FIFTY-SECOND ANNUAL REPORT

OF THE

SECRETARY

OF THE

STATE BOARD OF AGRICULTURE

OF THE

STATE OF MICHIGAN

AND

TWENTY-SIXTH ANNUAL REPORT

OF THE

EXPERIMENT STATION

FROM

JULY 1, 1912, TO JUNE 30, 1913.

BY AUTHORITY

LANSING, MICHIGAN
WYNKOOP HALLENBECK CRAWFORD CO., STATE PRINTERS
1913

REPORT OF THE SECRETARY

OF THE

STATE BOARD OF AGRICULTURE

East Lansing, Mich., *July 1, 1913.*

To Hon. Woodbridge N. Ferris,

Governor of the State of Michigan:

Sir—I have the honor to submit to you herewith, as required by law, the accompanying report for the fiscal year ending June 30, 1913, with supplementary papers.

Very respectfully,

ADDISON M. BROWN,

Secretary of the State Board of Agriculture.

STATE BOARD OF AGRICULTURE

	Term expires.
WILLIAM H. WALLACE, Saginaw	1st Monday January, 1916
I. ROY WATERBURY, Detroit	1st Monday January, 1916
JOHN W. BEAUMONT, Detroit	1st Monday January, 1918
JASON WOODMAN, Paw Paw	1st Monday January, 1918
ROBERT D. GRAHAM, Grand Rapids CHAIRMAN OF THE BOARD.	1st Monday January, 1920
ALFRED J. DOHERTY, Clare	1st Monday January, 1920
LUTHER L. WRIGHT, SUPT. OF PUBLIC INSTRUCTION,	*Ex-Officio*
JONATHAN L. SNYDER, PRESIDENT OF THE COLLEGE,	*Ex-Officio*

ADDISON M. BROWN, East Lansing, Secretary.

BENJAMIN F. DAVIS, Lansing, Treasurer.

STANDING COMMITTEES.

DIVISIONS OF AGRICULTURE AND OF VETERINARY SCIENCE	I. R. Waterbury, R. D. Graham.
DIVISION OF ENGINEERING	A. J. Doherty, J. W. Beaumont.
DIVISION OF HOME ECONOMICS	Jason Woodman, I. R. Waterbury.
DIVISION OF SCIENCE AND LETTERS	J. W. Beaumont, W. H. Wallace.
EXPERIMENT STATION	W. H. Wallace, A. J. Doherty.
EMPLOYEES	R. D. Graham, J. W. Beaumont.
FINANCE	R. D. Graham, W. H. Wallace.
FARMERS' INSTITUTES	A. J. Doherty, Jason Woodman.
BUILDINGS AND COLLEGE PROPERTY	I. R. Waterbury, Jason Woodman.

MICHIGAN AGRICULTURAL COLLEGE

(Under Control of the State Board of Agriculture.)

FACULTY AND OTHER OFFICERS.

Jonathan L. Snyder, A. M., Ph. D., LL. D., President; [a,b,c] Feb. 25, '96.

William J. Beal, Ph. D., D. Sc., Emeritus Professor of Botany; [a,b] June 9, '70; [c] June 15, '10.

Frank S. Kedzie, M. S., D. Sc., Professor of Chemistry; [a] Sept. 15, '80; [b,c] Sept. 1, '02.

Levi R. Taft, M. S., Superintendent of Farmers' Institutes and State Inspector of Orchards and Nurseries; [a] Aug. 1, '88; [b,c] July 1, '02.

||Warren Babcock, B. S., Professor of Mathematics; [a,b] June 30, '91; [c] July 1, '09.

Wilbur O. Hedrick, M. S., Ph. D., Professor of History and Economics; [a,b] Aug. 24, '91; [c] June 20, '06.

Herman K. Vedder, C. E., Professor of Civil Engineering; [a,b] Sept. 15, '91; [c] July 7, '09.

Walter B. Barrows, B. S., Professor of Zoology and Physiology and Curator of the General Museum; [a,b,c] Feb. 15, '94.

Rufus H. Pettit, B. S. in Agr., Professor of Entomology; [a] Jan. 1, '97; [b,c] Sept. 1, '06.

Joseph A. Jeffery, B. S. A., Professor of Soils and Soil Physics; [a] Sept. 1, '99; [b,c] Aug. 6, '08.

Maude Gilchrist, B. S., A. M., Dean of Home Economics; [a,b,c] Sept. 1, '01.

Addison M. Brown, A. B., Secretary of the College; [a,b,c] June 1, '02.

Robert S. Shaw, B. S. A., Dean of Agriculture; [a,b] Sept. 1, '02; [c] Jan. 15, '08.

Elida Yakeley, Registrar; [a] July 15, '03; [b,c] June 1, '08.

Arthur R. Sawyer, B. S., E. E., Professor of Physics and Electrical Engineering; [a,b,c] April 11, '04.

A. Crosby Anderson, B. S., Professor of Dairy Husbandry; [a] Sept. 1, '05; [b] June 10, '09; [c] June 15, '10.

George W. Bissell, M. E., Dean of Engineering and Professor of Mechanical Engineering; [a,b,c] June 18, '07.

J. Fred Baker, M. F., Professor of Forestry and Supervisor of Forest Reserve Lands; [a,b,c] Oct. 1, '07.

Ward Giltner, D. V. M., M. S., Acting Professor of Bacteriology and Hygiene; [a,b] July 1, '08; [c] Sept. 1, '12.

Harry J. Eustace, B. S., M. H., Professor of Horticulture; [a,b,c] Aug. 15, '08.

Victor T. Wilson, M. E., Professor of Drawing and Design; [a,b,c] Sept. 1, '08.

WALTER H. FRENCH, M. Pd., Professor of Agricultural Education; [a b c] Sept. 1, '08.

VERNON M. SHOESMITH, B. S. Professor of Farm Crops; [a b c] Feb. 14, '09.

ERNST A. BESSEY, Ph. D., Professor of Botany; [a b c] June 15, '10.

AGNES HUNT, B. S., Professor of Domestic Science; [a b c] Sept. 1, '10.

RICHARD P. LYMAN, B. S., M. D. V., Dean of Veterinary Science; Professor of Veterinary Medicine; [a b c] Sept. 28, '10.

JOHN F. MACKLIN, Professor of Physical Culture; Director of Athletics; [a b c] March 8, '11.

LIEUT. ANTON C. CRON, Professor of Military Science and Tactics; [a b c] Sept. 1, '11.

WILLIAM W. JOHNSTON, A. M., Professor of English Literature and Modern Languages; [a b c] Sept. 1, '12.

EBEN MUMFORD, Ph. D., State Director of Farm Management Field Studies; [a b c] Oct. 2, '12.

EDWARD H. RYDER, M. A., Associate Professor of History and Economics; [a] Sept. 1, '05; [b c] Oct. 21, '09.

CHACE NEWMAN, Assistant Professor of Drawing; [a] Sept. 1, '97; [b c] Sept. 1, '07.

E. SYLVESTER KING, Assistant Professor of English; [a] Jan. 1, '00; [b c] Sept. 1, '02.

JESSE J. MYERS, B. S., Assistant Professor of Zoology; [a b] Sept. 1, '01; [c] June 26, '07.

JOSEPH A. POLSON, B. S., Assistant Professor of Mechanical Engineering; [a b] Sept. 1, '06; [c] May 7, '08.

ARTHUR J. CLARK, A. B., Assistant Professor of Chemistry; [a b] Sept. 1, '06; [c] June 10, '09.

WYLIE B. WENDT, B. C. E., Assistant Professor of Civil Engineering; [a b] Sept. 1, '06; [c] May 26, '09.

WILLIAM L. LODGE, B. S., M. A., Assistant Professor of Physics; [a b] Oct. 1, '06; [c] Apr. 28, '09.

FRANK H. SANFORD, B. S., Assistant Professor of Forestry; [a b] Dec. 1, '06; [c] May 1, '09.

CHARLES P. HALLIGAN, B. S., Assistant Professor of Horticulture; [a b] Apr. 8, '07; [c] May 7, '08.

RICHARD DEZEEUW, Ph. D., Assistant Professor of Botany; [a b] Sept. 1, '09; [c] Sept. 1, '10.

EDWARD J. KUNZE, B. S., M. E., Assistant Professor of Mechanical Engineering; [a b c] Sept. 1, '10.

FRANK W. CHAMBERLAIN, B. S., D. V. M., Assistant Professor of Veterinary Science; [a b c] Jan. 1, '11.

JOHN S. MCDANIEL, B. S., D. V. S., Assistant Professor of Veterinary Surgery; [a b c] Sept. 1, '11.

CYRUS A. MELICK, D. C. E., Assistant Professor of Civil Engineering; [a b c] Sept. 1, '11.

CHARLES W. CHAPMAN, A. B., B. S., Assistant Professor of Physics; [a] Jan. 1, '07; [b c] Sept. 1, '11.

RALPH C. HUSTON, M. S., Assistant Professor of Chemistry; [a b c] Sept. 1, '11.

REUBEN L. NYE, B. S., Assistant Professor of Agricultural Education; [a b c] Sept. 1, '12.

The names of instructors whose resignations took effect between June 30 and Sept. 1, '12, do not appear below.

THOMAS GUNSON, Instructor in Horticulture and Superintendent of Grounds; [a b] April 1, '91; [c] Sept. 1, '05.
CAROLINE L. HOLT, Instructor in Drawing; [a b c] Sept. 1, '98.
LOUISE FREYHOFER, B. S., Instructor in Music; [a b c] Sept. 1, '02.
NORMA L. GILCHRIST, A. B., Instructor in English and German; [a b c] Sept. 1, '05.
L. ZAE NORTHRUP, B. S., Instructor in Bacteriology; [a b c] Sept. 1, '07.
MRS. MINNIE A. W. HENDRICK, A. B., Instructor in History and Economics; [a] Sept. 1, '07; [b c] Sept. 1, '08.
WILLIAM A. ROBINSON, A. B., S. T. B., Instructor in English; [a b c] Sept. 1, '07.
ROSE M. TAYLOR, A. B., Instructor in Botany; [a b c] Feb. 8, '08.
GEORGE D. SHAFER, Ph. D., Instructor in Entomology; [a] July 1, '08; [b c] Sept. 1, '08.
ISABEL P. SNELGROVE, Instructor in Drawing; [a b c] Sept. 1, '08.
GEORGE A. BROWN, B. S., Instructor in Animal Husbandry; [a b c] Sept. 1, '08.
MRS. LILLIAN L. PEPPARD, Instructor in Domestic Art and Domestic Science; [a b c] Sept. 1, '08.
WILLIAM E. LAYCOCK, Instructor in Physics; [a b c] Sept. 1, '08.
ANTOINETTE A. ROBSON, Instructor in German and English; [a b c] Jan. 1, '09.
BENJAMIN B. ROSEBOOM, JR., B. S., Instructor in Zoology; [a b c] Jan. 15, '09.
ANDREW WATT, Instructor in Blacksmithing; [a b c] April 1, '09.
MAURICE F. JOHNSON, B. S., Instructor in Mathematics; [a b c] April 1, '09.
CHARLES H. SPURWAY, B. S., Instructor in Soil Physics; [a b c] Sept. 1, '09.
HARRY H. MUSSELMAN, B. S., Instructor in Farm Mechanics; [a b c] Sept. 1, '09.
STANLEY E. CROWE, B. A., Instructor in Mathematics; [a b c] Sept. 1, '09.
*JAMES E. ROBERTSON, B. S., Instructor in Mathematics; [a b c] Sept. 1, '09.
ERNST E. BEIGHLE, B. S., Instructor in Mathematics; [a b c] Sept. 1, '09.
LLOYD C. EMMONS, B. S., A. B., Instructor in Mathematics; [a b c] Sept. 1, '09.
HUGH A. SNEPP, B. S., Instructor in Mathematics; [a b c] Sept. 1, '09.
FREDERICK A. BURT, B. S., Instructor in Zoology; [a b c] Sept. 1, '09.
RICHARD H. REECE, B. S., Instructor in Mathematics; [a b c] Jan. 1, '10.
DEWEY A. SEELEY, B. S., Instructor in Meteorology; [a b c] March 16, '10.
EUGENIA I. MCDANIEL, A. B., Instructor in Entomology; [a b c] April 1, '10.
SERG'T. PATRICK J. CROSS, Instructor in Military Science and Tactics; [a b c] May 1, '10.
RUTH F. ALLEN, Ph. D., Instructor in Botany; [a b c] Sept. 1, '10.
ANDREW M. OCKERBLAD, B. S. in C. E., Instructor in Civil Engineering; [a b c] Sept. 1, '10.
ERNEST A. EVANS, Instructor in Mechanical Engineering; [a b c] Sept. 1, '10.
*ERNST G. FISCHER, Ph. B., Instructor in German; [a b c] Sept. 1, '10.

Bertha E. Thompson, A. B., Instructor in Botany; [a b c] Sept. 1, '10.
Louis B. Mayne, A. B., Instructor in English; [a b c] Sept. 1, '10.
James L. Morse, Instructor in Mechanical Engineering; [a b c] Sept. 1, '10.
Arthur S. Smith, Instructor in Mechanical Engineering; [a b c] Sept. 1, '10.
Fred Killeen, Director of M. A. C. Chorus; [a b c] Sept. 1, '10.
Oren L. Snow, B. S., Instructor in Physics; [a b c] Sept. 1, '10.
George H. Coons, A. M., Instructor in Plant Pathology; [a b c] Jan. 1, '11.
W. Irving Gilson, B. S., Instructor in Forestry; [a b c] Jan. 1, '11.
Floyd E Fogle, Instructor in Farm Mechanics; [a b c] March 8, '11.
Frederick W. Bentzen, B. S., Instructor in Chemistry; [a b c] Sept. 1, '11.
Rachel M. Benham, B. S., Instructor in Bacteriology; [a b c] Sept. 1, '11.
Edward D. Kingman, Ph. B., Instructor in Civil Engineering; [a b c] Sept. 1, '11.
John R. Mitchell, A. B., Instructor in Chemistry; [a b c] Sept. 1, '11.
Walton S. Bittner, B. A., Instructor in English and German; [a b c] Sept. 1, '11.
Edith W. Casho, Instructor in Physical Culture; [a b c] Sept. 1, '11.
Milton Simpson, M. A., Instructor in English; [a b c] Sept. 1, '11.
Rufus P. Hibbard, Ph. D., Instructor in Plant Physiology; [a b c] Sept. 1. '11.
John O. Linton, B. S., Instructor in Poultry Husbandry; [a b c] Sept. 1, '11.
Bruce E. Hartsuch, A. B., Instructor in Chemistry; [a b c] Sept. 1, '11.
Charles S. Dunford, M. A., Instructor in Economics; [a b c] Sept. 1, '11.
Charles D. Curtiss, B. S., Instructor in Civil Engineering; [a b c] Sept. 1, '11.
George W. Hood, B. S., Instructor in Horticulture; [a b c] Sept. 1, '11.
Frans H. H. Van Suchtelen, Ph. D., Instructor in Bacteriology; [a b c] Sept. 1, '11.
Curtis L. Coffeen, B. S., Instructor in Farm Crops; [a b c] August 15, '12.
Mabel L. Leffler, Mus. B., Instructor in Music; [a b c] Sept. 1, '12.
Carl E. Newlander, B. S., Instructor in Dairy Husbandry; [a b c] Sept. 1, '12.
Guy A. Reddick, A. B., Instructor in Chemistry; [a b c] Sept. 1, '12.
Merton M. Cory, B. S., Instructor in Electrical Engineering; [a b c] Sept. 1, '12.
Allen C. Conger, B. S., M. A., Instructor in Zoology; [a b c] Sept. 1, '12.
Ora G. Yenawine, B. S., Instructor in Domestic Art; [a b c] Sept. 1, '12.
Virginia C. Richeson, A. B., Instructor in Domestic Science and Domestic Art; [a b c] Sept. 1, '12.
John P. Hutton, D. V. M., Instructor in Veterinary Surgery; [a b c] Sept. 1, '12.
Channing W. Parsons, B. S., Instructor in Civil Engineering; [a b c] Sept. 1, '12.
Carl Head, B. S., in M. E., Instructor in Drawing; [a b c] Sept. 1, '12.
Ralph E. Vennum, A. B., Instructor in English; [a b c] Sept. 1, '12.
Edward L. Shepard, B. S. in C. E., Instructor in Civil Engineering; [a b c] Sept. 1, '12.

DORA VON WALTHAUSEN, Instructor in French; [a b c] Sept. 1, '12.
EDWARD H. CONROY, Instructor in Chemistry; [a b c] Sept. 1, '12.
THOMAS W FITZGERALD, B. S., M. E., Instructor in Mechanical Engineering; [a b c] Sept. 1, '12.
CHARLES B. MITCHELL, M. A., Instructor in English; [a b c] Sept. 1, '12.
VERNE E. LEROY, A. B., M. S., Instructor in Zoology; [a b c] Sept. 1, '12.
DAMON A. SPENCER, B. S., Instructor in Animal Husbandry; [a b c] Sept. 1, '12.
WALTER G. WARD, B. S. in Archt., Instructor in Drawing; [a b c] Sept. 1, '12.
HOMER E. DENNISON, Instructor in Dairy Husbandry; [a b c] Sept. 1, '12.
ELAM T. HALLMAN, D. V. M., Instructor in Bacteriology; [a b c] Sept. 1, '12.
ORVILLE A. JAMISON, B. S. in Agr., Instructor in Dairy Husbandry; [a b c] Sept. 1, '12.
WILLIAM M. WIBLE, A. M., Instructor in Mathematics; [a b c] Oct. 1, '12.
STEPHEN V. KLEM, M. S., Instructor in Forestry; [a b c] Jan. 1, '13.
MARTIN G. FEUERHAK, Instructor in Mathematics; [a b c] Feb. 23, '13.
LINDA E. LANDON, Librarian; [a b c] Aug. 24, '91.
E. C. BAKER, Foreman of Foundry; [a b c] Nov. 1, '97.
LORY F. NEWELL, Engineer; [a b c] Jan. 1, '98.
BENJAMIN A. FAUNCE, Clerk to President and Editor M. A. C. Record; [a] Sept. 1, '99; [b c] Apr. 1, '10.
ROWENA KETCHUM, Nurse in Charge of College Hospital; [a b c] Sept. 1, '00.
ANDREW P. KRENTEL, Foreman of Wood Shop; [a b c] Sept. 1, '02.
CHARLES W. BROWN, B. S., Assistant in Bacteriology; [a b c] Aug. 1, '06.
WILLIAM R. HOLMES, Foreman of Forge Shop; [a b c] Sept. 1, '06.
JACOB SCHEPERS, Cashier; [a b] May 1, '07; [c] July 1, '07.
RALPH S. HUDSON, B. S., Farm Foreman; [a b c] Dec. 1, '07.
MAUD A. MEECH, Chief Clerk to Secretary; [a b] April 1, '08; [c] Sept. 1, '10.
ALBERT H. DAVIS, Foreman of the Horticultural Department; [a b c] Sept. 1, '08.
WILLIAM F. RAVEN, Live Stock Field Agent; [a b c] April 1, '09.
OLIVER K. WHITE, B. S., Horticultural Field Agent; [a b c] April 1, '09.
EDWARD C. CRAWFORD, Shop Engineer; [a b c] July 1, '09.
ROBERT J. BALDWIN, B. S., Executive Assistant to Dean of Agriculture; [a] Sept. 1, '09; [b c] Jan. 1, '10.
ARTHUR R. POTTS, Field Agent Soils and Crops; [a b c] Sept. 9, '09.
LOUISE E. WALSWORTH, Clerk to Secretary; [a b c] Jan. 17, '10.
WARREN S. ROBBINS, B. S., Assistant in Bacteriology; [a b c] Apr. 1, '11.
ELIZABETH M. PALM, B. S., Assistant Librarian; [a b c] July 15, '11.
BLANCHE A. BIRCHARD, Clerk to President; [a b c] Aug. 10, '11.
CHARLES D. BETTS, Purchasing Agent; [a b c] Sept. 1, '11.
JOHANNIS C. TH. UPHOF, in charge of Botanic Garden; [a b c] Feb. 23, '12.
COMFORT A. TYLER, Forestry Field Agent; [a b c] April 23, '12.
LENA M. MAXWELL, Assistant Cashier and Bookkeeper; [a b c] Aug. 1, '12.
JAY SMITH, Assistant in Machine Shop; [a b c] Sept. 1, '12.
MRS. MARY H. PAGE, House Director; [a b c] Sept. 1, '12.
LOUISE F. RAU, Clerk to Secretary; [a b c] Nov. 21, '12.

EXPERIMENT STATION WORKERS.

ANDREW J. PATTEN, B. S., Chemist; [a b c] Sept. 1, '05.
FRANK A. SPRAGG, M. S., Research Assistant in Farm Crops (Plant Breeding); [a b c] Dec. 1, '06.
CHARLES S. ROBINSON, M. S., Research Assistant in Chemistry; [a b c] Sept. 1, '09.
MYRA V. BOGUE, Bulletin Clerk; [a b c] Jan. 1, '10.
GEORGE J. BOUYOUCOS, Ph. D., Research Assistant in Soils; [a b c] June 19, '11.
WILLIAM C. MARTI, B. S., Assistant in Chemistry; [a b c] Sept. 1, '11.
LEO R. HIMMELBERGER, B. S., Assistant in Bacteriology; [a b c] July 1, '12.
ARAO ITANO, B. S., Research Assistant in Bacteriology; [a b c] Sept. 1, '12.

‖Deceased June 3, 1913.
*Resigned.
aFirst appointment.
bPresent appointment
cPresent title.

AGRICULTURAL EXPERIMENT STATION

OF THE

MICHIGAN AGRICULTURAL COLLEGE

(Under the control of the State Board of Agriculture.)

STATION COUNCIL.

Jonathan L. Snyder, A. M., Ph. D., L. L. D. - President *Ex-officio*.
Robert S. Shaw, B. S. A., - Director.
Ward Giltner, D. V. M., M. S., - Bacteriologist.
Harry J. Eustace, B. S., - Horticulturist.
J. Fred Baker, M. F., - Forester.
A. Crosby Anderson, B. S., - Dairy Husbandman.
Rufus H. Pettit, B. S. A., - Entomologist.
Andrew J. Patten, B. S., - Chemist.
Joseph A. Jeffery, B. S. A., - Soil Physicist.
Ernst A. Bessey, Ph. D., - Botanist.
Vernon M. Shoesmith, B. S., - Farm Crops Experimenter.
Addison M. Brown - - Secretary.

ADVISORY AND ASSISTANT STAFF.

Charles P. Halligan, B. S., - Asst. Horticulturist.
Elam T. Hallman, D. V. M., - Research Asst. in Bacteriology.
George A. Brown, B. S., - Asst. Animal Husbandman.
George D. Shafer, Ph. D., - Research Asst. in Entomology.
Charles W. Brown, B. S., - Research Asst. in Bacteriology.
Leo R. Himmelberger, B. S., - Asst. in Bacteriology.
Rufus P. Hibbard, Ph. D., - Research Asst. in Plant Physiology.
Geo. H. Coons, A. B., A. M., - Research Asst. in Plant Pathology.
Frank A. Spragg, M. S., - Research Asst. in Farm Crops (Plant Breeding.)
L. Zae Northrup, B. S., - Asst. Bacteriologist.
Linda E. Landon, - - Librarian.
Charles S. Robinson, M. S., - Research Asst. in Chemistry.
Frans H. H. Van Suchtelen, Ph. D., - Research Asst. in Bacteriology.
Wm. C. Marti, B. S., - Asst. in Chemistry.
Eugenia I. McDaniel, A. B., - Asst. in Entomology.
Geo. J. Bouyoucos, Ph. D., - Research Asst. in Soil Physics.
Arao Itano, B. S., - Research Asst. in Bacteriology.
Myra V. Bogue - Bulletin Clerk.

STANDING COMMITTEE IN CHARGE.

Hon. William H. Wallace - - - - - - - - - - - - - - Saginaw.
Hon. Alfred J. Doherty - - - - - - - - - - - - - - Clare.

STATE WEATHER SERVICE.

(Under the control of the State Board of Agriculture.)

OFFICER OF THE SERVICE.

Director - - - - - - - - - - C. F. Schneider, U. S. Weather Service.

ACCOUNTS OF

THE MICHIGAN AGRICULTURAL COLLEGE

FOR THE YEAR ENDING JUNE 30, 1913.

SECRETARY'S FINANCIAL REPORT.

			Dr.	Cr.
July 1, 1912.	Cash on hand		$2,475 67	
July 1, 1912.	Cash on deposit, College Treasurer		14,716 21	
June 30, 1913.	To special appropriation receipts		18,479 67	
	From State Treasurer	$11,000 00		
	From United States Treasurer	30,000 00		
	From institution and other sources	7,479 67		
June 30, 1913.	By special appropriation disbursements			$58,461 22
June 30, 1913.	To current account receipts		448,329 62	
	From State Treasurer, land grant interest	$70,289 30		
	From State Treasurer, one-tenth mill tax	208,800 00		
	From U. S. Treasurer, Morrill Fund	50,000 00		
	From institution and other sources	115,788 47		
	From South Haven Experiment Station	199 70		
	From U. P. Experiment Station	3,252 15		
	By general account disbursements			440,988 17
	From current account	$411,318 14		
	From supplementary accounts	29,670 03		
June 30, 1913.	By cash on hand			4,988 50
June 30, 1913.	By cash on deposit			9,563 28
			$514,001 17	$514,001 17

TABLE NO. 1.—*Tabular exhibit of Secretary's report.*

	Balance sheet July 1, 1912.		Transactions July 1, 1912 to June 30, 1913.		Balance sheet June 30, 1913.	
	Dr.	Cr.	Dr.	Cr.	Dr.	Cr.
Cash	$2,475 67			$2,512 83	$4,988 50	
College Treasurer*	14,716 21		$5,152 93		9,563 28	
Special appropriations		$5,350 37	48,479 67	58,461 22	4,631 18	
Current accounts		11,841 51	444,862 77	411,318 14		$19,182 96
Supplementary accounts			3,466 85	29,670 03		
Totals	$17,191 88	$17,191 88	$501,962 22	$501,962 22	$19,182 96	$19,182 96

*Treasurer's statement is greater July 1, 1912, by $9,288.58 and June 30, 1913, by $15,102.62; warrants outstanding.

TREASURER'S ACCOUNT.

	Dr.	Cr.
Balance on hand July 1, 1912	$24,004 79	
Receipts from State Treasurer, and Secretary of College	493,385 35	
Interest on deposits during year	911 11	
Warrants paid July 1, 1912 to June 30, 1913		$493,635 35
Balance on hand June 30, 1913		24,665 90
Total	$518,301 25	$518,301 25

TABLE NO. 2. *Statement of special appropriation accounts for the fiscal year ending June 30, 1913.*

Name of appropriation.	Balance of accounts, July 1, 1912.		Receipts during fiscal year.		Total available.	Total expended.	Balance of account, June 30, 1913.	
	Dr.	Cr.	From State Treasurer	From institution and other sources.			Dr	Cr.
Experiment Station	....	$957 91	†$30,000 00	$6,082 80	$37,040 71	$36,755 97	....	$284 74
Nursery License and Inspection	....	....	....	1,371 87	1,371 87	1,371 87	....	....
Sundry Improvements	....	1,378 49	....	....	4,378 49	3,249 68	....	1,128 81
Sayer Fund	....	12 50	....	25 00	37 50	25 00	....	12 50
Dairy Building	....	....	10,000 00	....	10,000 00	16,093 72	$6,093 72	....
Weather Bureau	....	1 47	1,000 00	....	1,001 47	964 98	....	36 49
Total	....	$5,350 37	$41,000 00	$7,479 67	$53,830 04	$58,461 22	$6,093 72	$1,462 51

†United States Treasurer.

TABLE NO. 3.—*William Smith Sayer Scholarship fund.*

Fund.	Year ending June 30.	Income.	Income expended to	Amount.	Balance including principal.
$500.00 received of F. F. Sayer, administrator of the estate of William Smith Sayer, to establish Scholarship in Bacteriology.......	1910	$32 25	A. McVittie	$19 75	$512 50
	1911	37 50	....	....	550 00
	1912	12 50	D. F. Fisher H. K. Wright	25 00 25 00	512 50
	1913	25 00	D. Francisco	25 00	512 50
		$107 25		$94 75	

TABLE NO. 4.—*Current account, July 1, 1912, to June 30, 1913.*

On account of—	Dr. To disbursements.	Cr. By receipts.
U. S. Treasurer, 23rd annual payment under act of Congress of August 1890	....	$50,000 00
State Treasurer, one-tenth mill fund	....	208,800 00
State Treasurer, interest on proceeds of sales of U. S. land grant	....	70,289 30
Advertising	$2,822 86	45
Agricultural Education	1,847 73	6 00
Animal Husbandry	9,277 39	5,770 05
Athletics	2,365 52	1,476 44
Bacteriology	14,019 03	14,576 63
Botany	2,281 78	260 58
Chemistry	11,128 63	5,397 34
Civil Engineering	2,693 12	807 60
Cleaning	3,191 12	728 94
College Extension	4,499 66	6 27
Contingent Building	23,127 71	34,338 07
Diploma fees, $965.00; incidentals, $9,252 50; matriculation, $2,480.00; room rent, $11,100 09; tuition, $2,540 00, delinquent, $377 00, sundry, $7,623 48.		
Crops	1,033 41	272 88
Dairy Husbandry	21,643 09	19,850 62
Dean's Office	1,639 59	15
Drawing	382 68	37 60
Electric Lighting	4,647 08	2,263 75
English	457 81	43 00
Entomology	1,058 45	28 41
Farm and Horses	9,649 99	7,100 28
Farm Management	745 02	4 55
Farm Mechanics	2,335 32	1,082 61
Forestry	5,197 60	910 27
Freight and Cartage	2,108 71	197 05
Graduate School Agriculture	4,601 20	3,020 00
Graduate School of Home Economics	692 74	320 00
Heating	29,866 68	569 33
History	309 07	20 00
Home Economics	4,531 42	1,819 90
Horticulture	7,413 61	1,067 49
Hospitals	502 47	188 68
Library	3,691 21	24 75
Mathematics	163 45	143 00
Mechanical Engineering	10,547 44	1,735 56
Meteorology	212 49	27 00
M. A. C. Record	1,343 85	526 50
Military	1,264 26	3 00
Miscellaneous	5,316 86	4,192 01
Office, President's	753 83	....
Office, Secretary's	2,237 99	763 48
Physics and Electrical Engineering	3,397 34	634 61
Poultry	2,508 29	456 65
Registrar	1,015 26	15 00
Salaries	190,449 22	2,218 66
Soils	1,727 25	2 00
Special Courses	3,190 39	1,595 00
Telephones	1,086 59	380 71
Veterinary	4,097 96	486 90
Zoology	1,943 97	403 70
Total	$411,318 14	$444,862 77
Supplementary accounts:		
Bulletins	4,917 42	15 00
Farmers' Institutes	8,875 56	....
South Haven Experiment Station	2,258 44	199 70
Upper Peninsula Experiment Station	13,618 61	3,252 15
Balance beginning of period July 1, 1912	....	11,841 51
Balance beginning of period July 1, 1913	19,182 96	....
Total	$460,171 13	$460,171 13

TABLE NO. 5.—*Experiment Station account for fiscal year ending June 30, 1913.*

On account of—	Disbursements.			Dr. Total disbursements each dept.	Cr. By receipts.
	Adams.	Hatch.	State.		
Balance July 1, 1912	....	....	....	....	$957 91
U. S. Treasurer for fiscal year	....	....	....	....	30,000 00
Fertilizer Fees	....	....	$20 00	$20 00	5,720 00
Bacteriological Dept	$1,513 60	$879 53	229 26	2,622 39	3 14
Botanical Dept	898 67	516 82	126 15	1,541 64	77 59
Chemical Dept	907 89	976 89	1,921 73	3,806 51	73 71
Director's Office	....	379 60	704 62	1,084 22	11 84
Entomological Dept	126 80	180 89	92 12	399 81	75
Farm Crops Dept	46 85	1,734 59	99 54	1,880 98	162 14
Horticultural Dept	....	825 44	55 49	880 93	....
Library	....	951 69	4 00	955 69	....
Salaries	10,869 06	8,554 55	3,338 45	22,762 06	10
Office, Secretary's	....	....	10 98	10 98	......
Soil Physicist	637 13	....	153 63	790 76	50
Balance June 30, 1913	....	....	....	284 74	....
Total	$15,000 00	$15,000 00	$6,755 97	$37,040 71	$37,040 71

TABLE NO. 6.—*Positions and salaries as shown by pay roll dated June 30, 1913.*

Grade.	Rate per year.	Classification. Current.	Classification. Experiment station.	Other sources.
Administration and Miscellaneous				
President's Office:				
President	$5,000 00	$5,000 00		House.
Editor M. A. C. Record	1,200 00	1,200 00		
Clerk	650 00	650 00		
Secretary's Office:				
Secretary	3,000 00	1,300 00	$700 00	$1,000 00 House.
Cashier	1,500 00	1,300 00	200 00	
Bookkeeper	800 00	700 00	100 00	
Chief Clerk	1,000 00	875 00	125 00	
Purchasing Agent	1,500 00	1,500 00		
Stenographer	600 00	600 00		
Clerk	650 00	650 00		
Registrar's Office:				
Registrar	1,200 00	1,200 00		
Institute and Nursery Inspector:				
Superintendent	2,300 00	2,300 00		House.
Library:				
Librarian	1,000 00	880 00	120 00	Rooms.
Asst. Librarian	600 00	600 00		
Miscellaneous:				
Engineer	1,200 00	1,200 00		
Plumber	900 00	900 00		
Night Watchman	600 00	600 00		
Nurse	500 00	500 00		
Leader of Band	250 00	250 00		
Instructor Meteorology	300 00	300 00		
Instructor, Chorus	240 00	240 00		
Stenographer	550 00	550 00		
Stenographer	550 00	550 00		
Stenographer	480 00	480 00		
Stenographer	480 00	480 00		
Stenographer	480 00	480 00		
Stenographer	480 00	240 00	240 00	
Stenographer	480 00	240 00	240 00	
Division of Home Economics				
Dean	1,700 00	1,700 00		Rooms.
Dept. Domestic Art:				
Instructor	1,000 00	1,000 00		Rooms.
Instructor	800 00	800 00		Rooms.
Dept. Domestic Science:				
Professor	1,500 00	1,500 00		Rooms.
Instructor	700 00	700 00		Rooms.
Instructor Music	1,100 00	1,100 00		
Asst. Instructor Music	600 00	600 00		Rooms.
Instructor Physical Culture	650 00	650 00		Rooms.
House Director	600 00	600 00		Rooms.
Division of Engineering				
Dean	3,000 00	3,000 00		House.
Clerk	600 00	600 00		
Dept. of Civil Engineering.				
Professor	2,500 00	2,500 00		House.
Asst. Professor	1,600 00	1,600 00		
Asst. Professor	1,500 00	1,500 00		
Instructor	1,300 00	1,300 00		
Instructor	1,000 00	1,000 00		
Instructor	850 00	850 00		
Instructor	1,000 00	1,000 00		
Instructor	800 00	800 00		

TABLE NO. 6.—*Continued.*

Grade.	Rate per year.	Classification. Current.	Experiment station.	Other sources.
Dept. of Drawing and Design:				
Professor	$2,300 00	$2,300 00		
Asst. Professor	1,500 00	1,500 00		
Instructor	850 00	850 00		
Instructor	750 00	750 00		
Instructor	750 00	750 00		
Instructor	750 00	750 00		
Dept. of Mechanical Engineering:				
Asst. Professor	1,900 00	1,900 00		
Asst. Professor	1,600 00	1,600 00		
Instructor	700 00	700 00		
Instructor	720 00	720 00		
Instructor	1,100 00	1,100 00		
Instructor	1,200 00	1,200 00		
Instructor	900 00	900 00		
Foreman Wood Shop	900 00	900 00		
Foreman Foundry	900 00	900 00		
Foreman Forge Shop	900 00	900 00		
Shop Engineer	780 00	780 00		
Dept. of Physics and Elec. Eng.				
Professor	2,300 00	2,300 00		
Asst. Professor	1,500 00	1,500 00		
Asst. Professor	1,400 00	1,400 00		
Instructor	1,100 00	1,100 00		
Instructor	1,100 00	1,100 00		
Instructor	950 00	950 00		
Division of Science and Letters				
Dept. of Bacteriology:				
Acting Professor	2,300 00	1,600 00	$700 00	
Asst. Bacteriologist	1,200 00	600 00	600 00	
Asst. Bacteriologist	1,500 00	250 00	1,250 00	
Instructor	800 00	800 00		
Asst. in Bacteriology	1,100 00	400 00	700 00	
Asst. in Bacteriology	1,300 00	1,300 00		
Research Asst. in Bacteriology	1,500 00	1,200 00	300 00	
Research Asst. in Bacteriology	900 00		900 00	
Research Asst. in Bacteriology	500 00		500 00	
Dept. of Botany:				
Professor	2,000 00	1,800 00	200 00	House
Asst. Professor	1,500 00	1,500 00		
Instructor	950 00	950 00		
Instructor	900 00	900 00		
Instructor	900 00	900 00		
Instructor	720 00	720 00		
Asst. in Botany	1,350 00	450 00	900 00	
Asst. in Botany	1,350 00	450 00	900 00	
Dept. of Chemistry:				
Professor	3,000 00	3,000 00		
Asst. Professor	1,600 00	1,600 00		
Asst. Professor	1,450 00	1,450 00		
Instructor	950 00	950 00		
Instructor	850 00	850 00		
Instructor	850 00	850 00		
Instructor	850 00	850 00		
Instructor	950 00	950 00		
Dept. of English:				
Professor	2,000 00	2,000 00		House
Asst. Professor	1,500 00	1,500 00		
Instructor	850 00	850 00		
Instructor	1,000 00	1,000 00		
Instructor	1,100 00	1,100 00		
Instructor	850 00	850 00		
Instructor	1,050 00	1,050 00		
Instructor	1,000 00	1,000 00		
Instructor	1,000 00	1,000 00		
Instructor	1,020 00	1,020 00		
Instructor	950 00	950 00		
Instructor	750 00	750 00		

TABLE NO. 6.—*Continued.*

Grade.	Rate per year.	Classification: Current.	Classification: Experiment station.	Other sources.
Dept. of Entomology:				
Professor	$2,000 00	$1,200 00	$800 00	House.
Instructor	900 00	550 00	350 00	
Research Asst. in Entomology	2,000 00	500 00	1,500 00	
Dept. of History:				
Professor	2,300 00	2,300 00		
Asst. Professor	1,800 00	1,800 00		
Instructor	850 00	850 00		
Instructor	1,000 00	1,000 00		
Dept. of Military Science:				
Sergeant	700 00	700 00		
Dept. of Mathematics:				
Instructor	900 00	900 00		
Instructor	1,100 00	1,100 00		
Instructor	1,100 00	1,100 00		
Instructor	1,400 00	1,400 00		
Instructor	1,000 00	1,000 00		
Instructor	1,000 00	1,000 00		
Instructor	1,080 00	1,080 00		
Instructor	800 00	800 00		
Instructor	875 00	875 00		
Dept. of Physical Culture:				
Director	2,300 00	2,300 00		
Dept. of Zoology:				
Professor	2,000 00	2,000 00		House.
Asst. Professor	1,600 00	1,600 00		
Instructor	1,100 00	1,100 00		
Instructor	1,000 00	1,000 00		
Instructor	1,000 00	1,000 00		
Instructor	800 00	800 00		
Division of Veterinary Science				
Professor	3,000 00	3,000 00		
Asst. Professor	1,800 00	1,800 00		
Asst. Professor	1,600 00	1,600 00		
Instructor	1,200 00	1,200 00		
Division of Agriculture				
Dean	3,000 00	2,000 00	1,000 00	House.
Clerk	1,200 00	700 00	500 00	
Dept. of Animal Husbandry:				
Instructor	1,500 00	1,300 00	200 00	
Instructor	900 00	900 00		
Dept. of Dairy Husbandry:				
Professor	2,300 00	2,000 00	300 00	
Instructor	1,100 00	1,100 00		
Clerk	550 00	550 00		
Instructor	900 00	900 00		
Dept. of Poultry:				
Instructor	1,200 00	1,200 00		
Dept. of Farm Crops:				
Professor	2,300 00	2,000 00	300 00	
Instructor	1,200 00	1,200 00		
Asst. to Farm Crop Exper'r	1,500 00		1,500 00	
Dept. of Soils:				
Professor	2,300 00	2,100 00	200 00	
Instructor	1,350 00	1,350 00		
Research Asst. in Soil Physics	1,350 00		1,350 00	
Dept. of Farm Mechanics:				
Instructor	1,500 00	1,500 00		
Instructor	850 00	850 00		
Instructor	900 00	900 00		

TABLE NO. 6.—*Concluded.*

Grade.	Rate per year.	Classification. Current.	Experiment station.	Other sources
Dept. of College Extension:				
Field Agent Live Stock..	$1,700 00	$1,700 00	....	
Field Agent Farm Crops.......	950 00	950 00	......	
Field Agent Horticulture	1,650 00	1,650 00	....	
Field Agent Forestry...........	1,500 00	1,500 00	.	
Dept. of Farm and Horses:				
Foreman College Farm.......	1,000 00	1,000 00	.	
Dept. of Agricultural Education:				
Professor.................	2,800 00	2,800 00	....	
Instructor..............	1,400 00	1,400 00	....	
Dept. of Forestry:				
Professor................	2,300 00	2,100 00	$200 00	
Asst. Professor...........	1,700 00	1,700 00	....	
Instructor.............	1,500 00	1,500 00	....	
Dept. of Horticulture:				
Professor............	2,500 00	2,300 00	200 00	House
Asst. Professor..........	1,800 00	1,600 00	200 00	
Instructor........	1,200 00	1,200 00	......	House
Instructor.....	1,200 00	1,200 00	....	
Foreman of Grounds.........	700 00	700 00	....	House
Chem. Div. Exp. Station:				
Chemist......................	2,300 00	....	2,300 00	
Research Asst. in Chemistry...	1,500 00	....	1,500 00	
Asst. in Chemistry	1,200 00	....	1,200 00	
Bulletin Clerk...............	600 00	...	600 00	
Director Farm Management.....	800 00	800 00	.	
Total..................	$216,885 00	$193,010 00	$22,875 00	$1,000 00

TABLE NO. 7.—*Income of the Michigan Agricultural College from all outside sources from the date of its foundation to the present time.*

Year.	From State Legislature. For current expenses.	From State Legislature. For special purposes.	Land sales, salt spring and swamp land grants.	From U. S. Congress. Morrill act of 1862, interest from land grant and trespass.	From U. S. Congress. Hatch act of 1887, and Adams act of 1906, experiment station.	From U. S. Congress. Morrill act of 1890, supplementary endowment.	Total.
1855			$56,320 00				$56,320 00
1856							
1857	$40,000 00						40,000 00
1858							
1859	37,500 00						37,500 00
1860							
1861	6,500 00		152 25				6,652 25
1862	10,000 00		218 97				10,218 97
1863	9,000 00		407 80				9,407 80
1864	9,000 00		726 09				9,726 09
1865	15,000 00		1,156 61				16,156 61
1866	15,000 00		1,094 27				16,094 27
1867	20,000 00		7,608 38				27,608 38
1868	20,000 00		592 49				20,592 49
1869	20,000 00	$30,000 00	17,559 00	$58 96			67,617 96
1870	20,000 00		1,320 02	2,720 93			24,040 95
1871	18,250 00	10,500 00	4,135 72	3,785 54			36,671 26
1872	18,250 00	3,000 00	217 05	7,175 65			28,642 70
1873	21,796 00	15,602 00	10 13	11,059 06			48,467 19
1874	13,000 00	15,602 00	150 13	14,061 98			42,814 11
1875	7,638 00	7,755 50	144 53	14,446 14			29,984 17
1876	7,638 00	6,755 50	1,773 09	16,830 17			32,996 76
1877	6,150 00	30,686 80	979 06	15,172 86			52,988 72
1878	6,150 00	5,686 80	826 60	15,807 09			28,470 49
1879	4,971 80	16,068 32	712 22	16,978 22			38,730 56
1880	4,971 80	7,068 32	797 55	17,837 24			30,674 91
1881	7,219 00	43,720 50	461 95	20,935 25			72,366 70
1882	7,219 00	8,915 50	358 46	22,507 45			39,060 41
1883	8,385 00	23,793 00	391 95	30,749 60			63,319 55
1884	8,385 00	10,526 00	1,259 90	27,909 72			48,080 62
1885		35,103 00	187 50	29,770 40			65,060 90
1886		22,617 00		30,461 04			53,078 04
1887		*44,010 00	198 20	†24,611 37			68,849 57
1888		30,752 50	144 20	32,406 60	$15,000 00		78,303 30
1889		*20,973 00	10 50	31,322 69	15,000 00		67,306 19
1890		*27,172 00	238 50	32,360 64	15,000 00	$15,000 00	89,771 14
1891		22,947 50	37 38	34,750 54	15,000 00	16,000 00	88,735 42
1892		22,947 50	137 38	34,948 12	15,000 00	17,000 00	90,033 00
1893		18,862 50	10 50	37,927 04	15,000 00	18,000 00	89,800 04
1894		18,862 50	433 59	41,527 26	15,000 00	19,000 00	97,823 35
1895		‡19,000 00	10 50	45,301 85	15,000 00	20,000 00	99,312 35
1896		‡16,000 00		43,886 40	15,000 00	21,000 00	95,886 40
1897		§17,700 00		43,779 51	15,000 00	22,000 00	98,479 51
1898		‖17,500 00		47,508 28	15,000 00	23,000 00	103,008 28
1899		¶8,750 00	705 00	52,526 11	15,000 00	24,000 00	100,981 11
1900		¶72,500 00	175 00	72,298 38	15,000 00	25,000 00	184,973 38
1901††		¶72,500 00		63,976 79	15,000 00	25,000 00	176,476 79
1902	100,000 00	**1,000 00		64,081 81	15,000 00	25,000 00	205,081 81
1903	100,000 00	**1,000 00		65,573 90	15,000 00	25,000 00	206,573 90
1904	100,000 00	**1,000 00	61 19	67,312 37	15,000 00	25,000 00	208,373 50
1905	100,000 00	**1,000 00		72,035 32	15,000 00	25,000 00	293,035 32
1906	157,810 00	15,000 00		70,286 56	15,000 00	25,000 00	283,096 56
1907	173,110 00	**1,000 00		70,455 22	23,691 60	25,000 00	293,256 82
1908	173,110 00	**1,000 00		70,385 79	23,326 10	30,000 00	298,121 89
1909	173,110 00	**1,000 00		69,527 13	26,000 00	35,000 00	301,937 13
1910	173,110 00	**1,000 00		71,109 49	28,000 00	40,000 00	313,519 49
1911	173,110 00	**1,000 00		70,304 15	30,000 00	45,000 00	319,714 15
1912	228,800 00	**1,000 00		70,265 32	30,000 00	50,000 00	380,065 32
1913	228,800 00	**1,000 00		70,289 30	30,000 00	50,000 00	380,089 30
Totals	$2,214,543 60	$829,937 74	$101,723 66	$1,771,725 27	$476,017 70	$645,000 00	$6,068,917 97

*Including appropriation for weather service.
†October 1, 1886, to June 30, 1887, nine months.
‡Including $5,000 for institutes and $1,000 for weather service.
§Including $5,500 for institutes and $1,000 for weather service.
‖Including $5,500 for institutes and $1,000 for weather service.
¶Including $2,750 for institutes and $500 for weather service.
††To June 30. **Weather service.

SUMMARY OF INVENTORY, JUNE 30, 1912.

College farm and park, 671 acres		$67,100 00
Athletic field and drive, 13 acres		1,300 00
Buildings—		
Library and museum, built 1881	$22,000 00	
College hall, built 1856	12,000 00	
Wells hall, rebuilt 1905-06	55,000 00	
Williams hall, built in 1869	30,000 00	
Abbot hall, built 1888, addition in 1896	15,000 00	
Chemical laboratory, built 1871, south end addition 1881, east end addition 1911	35,000 00	
Machine shops and foundry, 1885, south end addition 1887	15,000 00	
Veterinary laboratory, built 1885	5,000 00	
Horticultural laboratory, built 1888	7,000 00	
Entomological laboratory, built 1889, imp. 1897	7,500 00	
Botanical laboratory, built 1892, imp. 1909	20,000 00	
Armory, built 1885	6,000 00	
Greenhouse and stable, built 1873, 1879, rebuilt 1892 and 1902	6,000 00	
Boiler house and chimney, built 1893-4	3,000 00	
President's and two frame dwellings, built 1874	12,000 00	
Six brick dwellings, built 1857, 1879 and 1884	18,000 00	
One frame house, built 1885	3,500 00	
Howard Terrace dwelling, built 1888	13,000 00	
Farm house dwelling, built 1869	2,000 00	
Herdsman's dwelling, built 1867	400 00	
Six barns at professors' houses	1,050 00	
Horticultural barn and shed, built 1868, 1875 and 1877	1,200 00	
Bull barn, rebuilt 1905	1,500 00	
Sheep barn, rebuilt 1906	2,500 00	
Horse barn, built 1906	5,000 00	
Grade herd barn, rebuilt 1905	4,000 00	
Piggery, rebuilt 1907	1,500 00	
Dairy barn, rebuilt 1900	4,000 00	
Farm mechanics building, built 1881	1,500 00	
Poultry house, built 1906	1,000 00	
Incubator house, built 1906	500 00	
Poultry house, built 1907	1,500 00	
Three poultry houses, built 1907	300 00	
Ten brooder houses, built 1908	250 00	
Corn barn, built 1878	400 00	
Stock judging barn, built 1894	200 00	
Brick work shop, built 1857	500 00	
Observatory, built 1880	100 00	
Bath house and fittings, built 1902-3	17,000 00	
Paint shop, rebuilt 1903	300 00	
Hospital, built 1894	3,000 00	
Waiting room and book store, built 1902	1,700 00	
Lumber shed, mechanical department	250 00	
Three silos	600 00	
Coal shed, built 1899	700 00	
Women's building, built 1900	91,000 00	
Dairy building, built 1900	15,000 00	
Bacteriological building, built 1902	27,000 00	
Power house, built 1904	25,000 00	
Amount carried forward	$495,950 00	$68,400 00

Amount brought forward	$495,950 00	$68,400 00
Buildings—Continued.		
Coal shed, built 1905	6,500 00	
Tunnel system, built 1904	45,000 00	
Cold storage, rebuilt 1905	2,000 00	
Engineering building, built 1906-07, including heating	110,000 00	
Iron bridge over Cedar river, built 1888	1,500 00	
Bridge to athletic field	500 00	
Manure shed	600 00	
Four hospital cottages, built 1909	6,000 00	
Agricultural building, built 1909	182,000 00	
Lumber shed, built 1911	650 00	
Tile silo	500 00	
Piggery for serum production	1,000 00	
		852,200 00
Division of Agriculture—		
Department of Agricultural Education		624 04
Department of Animal Husbandry—		
Office library	$1,009 87	
Office	193 64	
Live stock	8,735 50	
Feed	438 30	
Miscellaneous	351 25	
		10,728 56
Department of Farm Crops		2,070 35
Department of Dairy Husbandry—		
Live stock	$8,145 00	
Dairy barn	622 10	
Office	714 58	
Live stock library	611 00	
Dairy building equipment	1,419 92	
Miscellaneous	768 55	
		12,281 15
Dean's office		2,275 53
Department of Farm and Horses—		
Horses	$8,850 00	
Office	303 07	
Small horse barn	103 14	
Corn crib	277 15	
Large horse barn	1,657 38	
Tool barn	1,865 66	
		13,056 40
Department of Farm Mechanics—		
Office	$353 30	
Cement laboratory	319 04	
Wood shop	1,231 05	
Forge shop	1,590 77	
Machine laboratory	1,738 33	
		5,232 49
Department of Forestry—		
Office	$406 08	
Wood technology	1,764 00	
Dendrology equipment	1,025 88	
Photographic supplies	1,061 46	
Camp equipment	1,751 31	
Nursery utensils	253 81	
Nursery stock	3,664 15	
Silviculture	15 35	
Specimens	20 20	
Books	406 35	
Exhibits	756 03	
		11,124 62
Amount carried forward		$977,993 14

Amount brought forward		$977,993 14
Department of Horticulture		
Office	$1,593 13	
Tools	797 78	
Classroom	393 50	
Laboratory equipment	482 75	
Teams and harness	1,033 50	
Greenhouse plants	1,064 25	
		5,364 91
Department of Poultry		2,182 47
Department of Soils—		
Apparatus and supplies	$3,142 43	
Furniture	503 24	
Photographic supplies	149 71	
College extension	16 40	
Chemicals	38 45	
		3,850 23
Division of Engineering—		
Department of Civil Engineering—		
Astronomical equipment	$1,598 55	
Blue printing, drawing and photography	263 86	
Cement laboratory	1,994 56	
Drafting and computing devices	4,383 31	
Hydraulic laboratory	2,057 73	
Library	320 84	
Surveying instruments	10,910 98	
Tools	85 67	
		21,615 50
Department of Drawing and Design		5,654 52
Department of Mechanical Engineering—		
Office and classroom equipment and supplies	$12,040 78	
Experimental laboratory	14,861 27	
Machine shop	14,605 17	
Forge shop	2,310 52	
Foundry	1,701 92	
Wood shop	4,619 92	
		50,139 58
Department of Physics and Electrical Engineering—		
Furniture	$2,983 63	
Shop and stock	601 94	
Mechanics	1,632 40	
Sound	174 30	
Light	1,775 55	
Heat	625 05	
Electricity and magnetism	3,488 80	
Condensers	231 75	
Galvanometers	557 00	
Resistance boxes	1,018 92	
Standard resistances	89 50	
Bridges	486 00	
Motors and generators	6,314 00	
Wattmeters	658 00	
Voltmeters	716 00	
Ammeters	705 75	
Starting boxes	113 00	
Transformers	1,483 00	
Rheostats	170 50	
Miscellaneous	1,227 42	
		25,052 51
Amount carried forward		$1,091,852 86

Amount brought forward		$1,091,852 86
Division of Home Economics—		
Reception room and hall	$731 19	
Dean's office	239 64	
Gymnasium office	144 81	
Gymnasium	554 43	
Day Student's waiting room	215 20	
Recitation room	45 85	
Parlor	651 00	
Guest room	65 85	
Second floor	192 20	
House library	88 55	
Music room	2,703 00	
Domestic science	1,244 72	
Domestic art	1,040 03	
Howard Terrace	500 02	
Dormitory furniture	1,536 21	
Miscellaneous	209 01	
Laundry	125 81	
		10,287 52
Miscellaneous—		
Carpenter shop		3,018 79
Cleaning		673 46
Farmers' Institutes		503 35
Hospital, general		261 93
Hospital cottages		875 90
Nursery and orchard inspection		62 85
Paint shop		1,113 96
President's office		912 40
Registrar's office		342 65
Secretary's Office—		
Furniture and equipment	$917 99	
Supplies	1,712 74	
		2,630 73
Weather service		1,169 77
Division of Science and Letters—		
Department of Bacteriology—		
Literature	$562 41	
Chemicals	1,081 87	
Apparatus	8,771 03	
Furniture and office supplies	967 58	
		11,382 89
Department of Botany—		
Apparatus and supplies	$726 99	
Miscellaneous	571 90	
Books and charts	1,184 35	
Botanical museum	50 00	
Chemicals	106 08	
Furniture	1,848 50	
Glassware and porcelain	515 78	
Herbarium	6,790 30	
Microscopes	3,280 15	
Tools	60 90	
		15,134 95
Department of Chemistry—		
Furniture and fixtures	$6,627 07	
Graduated glassware	1,871 07	
Ungraduated glassware	6,213 14	
Organic chemicals	419 00	
Inorganic chemicals	1,257 42	
Electrical supplies	1,249 88	
Apparatus and supplies	14,579 76	
Specimens	354 00	
Tools	523 10	
Amount carried forward	$33,094 44	$1,140,224 01

Amount brought forward	$33,091 11	$1,110,221 01
Department of Chemistry—Continued—		
Assay room supplies	266 50	
Miscellaneous	319 60	
		33,680 54
Department of English		900 52
Department of Entomology—		
Furniture and collections	$3,706 52	
Books and charts	246 81	
Apparatus	1,221 86	
Supplies	463 59	
		5,638 78
Department of History and Economics		557 75
Library		63,261 48
Department of Mathematics—		
Office furniture	$248 80	
Books	56 58	
		305 38
Department of Meteorology		87 86
Department of Military Science and Tactics—		
Furniture and fixtures	$1,256 29	
Band properties	1,366 00	
		2,622 29
Department of Physical Culture and Athletics—		
Armory and gymnasium	$453 00	
Bath house	40 40	
Office	263 25	
Athletic field	133 10	
		889 75
Department of Physiology and Zoology—		
General museum	$18,888 00	
Academic department	2,842 60	
Dissecting department	50 45	
Drawing instruments and material	10 95	
Geological apparatus	261 99	
Microscopes	2,979 37	
Photographic supplies	216 85	
Tools	132 23	
Miscellaneous	533 43	
		25,915 87
Division of Veterinary Science—		
General equipment	$670 04	
Pharmacology	689 94	
Surgery	1,266 18	
Anatomy	3,685 28	
		6,311 44
Division of Water, Heat and Light—		
Telephone department	$2,838 89	
Office furniture	119 50	
Water works plant	10,150 00	
Fire department	2,729 00	
C. B. E. stock	3,517 81	
C. B. E. tools	1,960 77	
Steam heating plant	16,588 00	
Heating stock	2,927 90	
Electric light stock	2,834 06	
		43,665 93
Total		$1,324,061 60

SUMMARY OF EXPERIMENT STATION INVENTORY.

Lands donated to the station—		
80 acres at Grayling, fenced and improved at cost	$1,000 00	
5 acres at South Haven, fenced and improved	1,000 00	
160 acres at Chatham, including buildings	6,000 00	
620 acres at Chatham, unimproved	6,200 00	
		$14,200 00
Buildings—		
Bacteriological stable	$3,700 00	
House	1,000 00	
Station Terrace building	3,000 00	
Seed room	500 00	
Slaughter house	625 00	
Storage barn	600 00	
Insectry	1,000 00	
Soil house	1,000 00	
		11,425 00
Experiment Station—		
Division of Bacteriology—		
Literature	$2,179 64	
Apparatus	9,510 57	
Fixtures and office supplies	258 59	
Chemicals	729 32	
		12,678 12
Division of Botany—		
Scientific apparatus	$2,478 89	
Microscopes and photo apparatus	880 56	
Laboratory supplies	206 63	
Glassware	290 70	
Books	104 97	
Office furniture and supplies	497 23	
Chemicals	249 35	
		4,708 33
Bulletin room		453 82
Division of Chemistry—		
Chemicals	$468 46	
Glassware	1,173 53	
Porcelain ware	181 94	
Office furniture and supplies	541 73	
Miscellaneous	3,882 67	
		6,248 33
Director's office		469 18
Division of Entomology—		
Furniture and supplies	$580 37	
Miscellaneous	2,206 57	
Books	958 48	
Apparatus	1,473 79	
Chemicals and chemical supplies	254 74	
Stains	18 68	
Spraying machinery	56 20	
Tools	21 02	
Glassware	439 36	
		6,009 21
Farm Division		2,068 27
Division of Horticulture—		
Sundry	$1,126 75	
Tools	161 80	
		1,288 55
Experiment Station Library		7,081 50
Division of Soils		1,049 88
South Haven Experiment Station		309 56
Upper Peninsula Experiment Station		2,068 37
Total		$70,058 12

REPORT OF THE PRESIDENT.

To the Honorable State Board of Agriculture:

The President of the College has the honor to submit to the State Board of Agriculture the following report for the year ending June 30, 1913. This report, as in previous years, will be published as a part of the full report which is annually issued by the college under the title "Report of the Secretary of the State Board of Agriculture." These reports, which give a full history of the college as well as all bulletins issued by the Experiment Station, date back to the beginning of agricultural education in this country and form a record which will be highly prized some day as an authentic record of agricultural development.

As this report contains a very full record of the various departments of the college, it has not seemed necessary nor wise for the President to issue an elaborate report each year which would necessarily duplicate in a large measure, the annual report issued by the college. This report therefore, will be limited to the few matters which will not otherwise be made a part of the report which the Secretary of the College is required by law to issue.

The work accomplished during the year was very satisfactory. The health of the students was unusually good and nothing occurred to interfere with the regular work of the students and faculty. The attendance in the regular college classes was larger than in any previous year although the total enrollment, due to certain changes in the short courses, was not quite so large as the enrollment of the previous year.

The graduating class numbered 165. Of this number 69 were graduated from the Agricultural course, 51 from the course in Engineering, 30 from the Home Economics course, 14 from the Forestry course and 1 from the course in Veterinary Medicine.

Advanced degrees were granted to 30 former graduates of the college who had met all the requirements as set forth in the college catalog. Ten received the degree of C. E., 5 the degree of M. E., 1 was awarded the degree of M. H., 2 the degree of M. A., 2 the degree of M. F., and 6 the degree of M. H. E.

The names and addresses of the graduating class and also those receiving advanced degrees will be found later in this report.

The degree of Master of Science in course was granted to the following persons: John Carlton Hurley, Macedon, N. Y.; Charles Jay Oviatt, Bay City, Mich.; Charles Burt Ross, Morgantown, W. Va. and Constantine Nicholas Svetlikoff, Suzran, Russia.

Mr. Charles E. Bassett of Fennville and Mr. James K. Jakway of Benton Harbor, both of whom were former students of the college and have rendered conspicuous service to the horticultural interests of the state, were awarded the honorary degree of Master of Horticulture.

J. Henry Moores, who was a student in the college from 1865 to 1868 and who is serving his day and generation in a most generous and public spirited manner, was selected for the honorary degree of Master of Arts.

The degree of Doctor of Science was conferred upon two former graduates of the college, W. A. Taylor of the class of '88 and now Chief of the Bureau of Plant Industry of the Department of Agriculture, Washington, and Professor Warren Babcock, the head of the Department of Mathematics of the college.

Professor Babcock was taken by death before the public announcement of the honor conferred upon him by his Alma Mater on Commencement day.

Commencement exercises were held in a large tent in which was also held the Alumni banquet.

The Baccalaureate sermon was given on June 22nd by the Rt. Rev. Charles D. Williams, of Detroit, Bishop of Michigan.

The address to the graduating class was delivered by Miss Ida M. Tarbell, Associate Editor of American Magazine.

The Triennial reunion of the Alumni was held on the day following Commencement and was attended by between six and seven hundred graduates of the college. These triennial meetings are mile-stones in the history of the college. The semi-centennial meeting six years ago was particularly significant. At that meeting a record of progress and development was noted which was gratifying to the friends of the college. A brief comparison of the status of the college at that time and the present will show something of the progress of recent years:

In 1907 there were 17 full professors; in 1913 there were 25.

In 1907 there were 3 assistant and associate professors; in 1913 there were 23.

In 1907 there were 52 instructors; in 1913 there were 84.

In 1907 there were 92 in the teaching force not including extension men; in 1913 there were 152.

In 1907 the average salary paid associate and assistant professors was $1265. At present the average is $1691.

In 1907 the average salary paid instructors was $827, and at present $1050.

The number of students enrolled in 1907 was 1000 and at present 1643.

COURSES OF STUDY.

The courses of college grade will be continued without change or modification during the coming year. It has been decided by the Board upon recommendation of the Faculty, to discontinue the five year course after next year. While this course has served a useful purpose, it is believed that the time has come when the college can, with the means at its disposal, serve a higher purpose than to offer work which belongs to the preparatory school. The college will endeavor in some way to take care of the few meritorious cases each year which cannot be properly cared for by the secondary schools of the state.

The eight week courses which are held during January and February and which have been so popular and successful in the past, will be augmented by the addition of a seven weeks term which will be held during November and December. This will make practically a contin-

nous term of fifteen weeks. A second year of instruction will be offered to those who complete successfully the first year, thus making a two year winter course in practical agriculture. These courses will be open to students from the public schools who have attained the age of seventeen years.

FACULTY.

The college loses this year three prominent members of its faculty.

Professor Warren Babcock, who had been ill for nearly two years, departed this life on June 3rd. Professor Babcock after graduation from the Milan High School, entered the freshman class of this college in the fall of 1885 and graduated with the class of 1890. He was at once employed as an instructor in the Department of Mathematics and Civil Engineering and in due time was promoted to the rank of Associate Professor. When mathematics was made an independent department in 1909, he was placed at its head and served in this capacity until his death. He also rendered very valuable service to the college as Secretary of the Faculty. He was devoted to the interest of the college and was unsparing in his efforts in its behalf.

Miss Maude Gilchrist, who has been in charge of the Women's Department as Dean during the past twelve years, resigned at the close of the year to accept an Associate Professorship in Botany in her Alma Mater—Wellesley. The splendid development of this department has been due in no small measure to the good judgment, keen initiative and courageous efforts of the Dean. She brought to the position the very best of training in scholarship and experience; thorough preparation reinforced with the very highest qualities of character made her administration one of signal success. The College regrets to lose her services.

Miss Georgia White, A. B. Ph. D., who will succeed Miss Gilchrist is a graduate of Lake Erie College and after studying abroad, completed her work for the Doctor's degree at Cornell University. She taught Sociology in Smith College for eight years and has been Dean of Women at Olivet College during the past two years.

Professor J. A. Jeffery, who has served the college for the past fourteen years, first as head of the Agronomy department and after this department was divided in 1902, as head of the Department of Soils, has resigned to accept a more lucrative position as head of the Farm department of the Duluth and South Shore Railroad.

Professor Jeffery has rendered the college very faithful and efficient service. He has been an honest, willing worker and has brought to his task not only thorough training but a sincerity of purpose which has made his influence on students and associates count for great and permanent good. It will be difficult to find a successor of such sterling qualities of character.

BUILDINGS.

The college has under construction a dairy building which when completed will very adequately meet the needs of this department. Plans are also under way for the erection of a building for the Veterinary division.

It will be a number of years before all the buildings now needed by

the institution can be provided. It is encouraging, however, that there is good reason to believe that new buildings to meet all needs can be provided within the next few years.

FIELD MEN.

The college is rapidly increasing the work carried on outside of the institution. Five men have been giving their full time to extension work. This number will be increased by the addition of several men in the near future. Three district men and eleven county men are employed in co-operation with the Government. It is expected also that there will be an increase in this number in the near future.

Twenty-one high schools in the state last year offered full courses in agriculture. Agriculture in these schools was taught by graduates of the college. Next year more than thirty high schools will offer full courses in agriculture. Last year in connection with the high schools teaching agriculture, one week courses in agriculture were offered to the farmers of the neighborhood. These were well attended and on the whole were very successful. It is planned also to increase this line of work next year.

The last Legislature increased the mill tax from one-tenth to one-sixth of a mill. One-tenth of a mill yielded an annual income of $228,000.00. The new rate will give the college an income of $381,000.00. This will be increased automatically next year, probably not less than 25% and each third and fifth year thereafter, the amount will be increased to correspond with the increase in the valuation of the property of the state. This fund is believed to be sufficient to take care of the growing needs of the college and at the same time to add during the next few years new buildings to the extent in value of $100,000 to $150,000 per annum.

The State Board has been fortunate in securing both by purchase and by contract to purchase, the Woodbury farm lying across the river from the west part of the campus. This farm consists of 335 acres and comes within a quarter of a mile of the center of the campus and is joined on both the north and east sides by the college farm. This will make it possible to greatly enlarge the athletic field and also to develop a large drill ground across the river. The present drill ground has become entirely too small for the twelve companies now forming the battalion. The farm is also greatly needed for the growing of crops and general farm purposes. It is believed that the wisdom of this purchase will be much appreciated in years to come.

For information concerning the work of the various departments of the college, please consult their reports herewith submitted.

The following statistics concerning student enrollment may be of interest.

J. L. SNYDER,
President.

East Lansing, Mich., June 30, 1913.

PREPARATION OF NEW STUDENTS.

High School Diploma	333	
High School credits	79	
Examinations	18	
From other colleges	37	
Age	27	
		494

WITHDRAWALS.

	1st term.	2nd term.	3rd term.		
Withdrawn voluntarily	69	29	6	104	
Withdrawn by Faculty (work)	9	9	26	44	
Withdrawn by Faculty (discipline)		5	1	9	
Withdrawn by Faculty (dishonesty)	1			1	
					158

NUMBER OF STUDENTS IN ATTENDANCE.

FOUR YEAR COURSES.

Agriculture and Forestry	481	
Engineering	391	
Home Economics	245	
Veterinary	19	
		1136

SUB-FRESHMAN YEAR.

Agriculture and Forestry	60	
Engineering	40	
Home Economics	17	
Veterinary	2	
		119

SPECIAL STUDENTS.

Agriculture and Forestry	46	
Engineering	3	
Home Economics	10	
Veterinary	3	
		62

Winter Short Courses, Agriculture	326	326
Graduate students		4
Total number of students in attendance		1647

COUNTIES REPRESENTED IN ENTERING CLASS.

Allegan	10	Lapeer	4
Alpena	3	Leelanau	3
Antrim	3	Lenawee	7
Barry	4	Livingston	1
Bay	10	Mackinac	3
Benzie	1	Macomb	4
Berrien	8	Manistee	1
Branch	6	Marquette	8
Calhoun	10	Mason	6
Cass	3	Mecosta	2
Cheboygan	1	Midland	6
Chippewa	2	Monroe	1
Clinton	9	Montcalm	1
Delta	1	Muskegon	5
Dickinson	3	Newaygo	5
Eaton	9	Oakland	15
Genesee	16	Oceana	3
Gogebic	4	Ottawa	5
Grand Traverse	6	Roscommon	1
Gratiot	2	Saginaw	6
Hillsdale	8	Sanilac	2
Houghton	12	Schoolcraft	6
Huron	5	Shiawassee	5
Ingham	62	St. Clair	6
Ionia	10	St. Joseph	5
Iosco	4	Tuscola	7
Isabella	2	Van Buren	13
Jackson	13	Washtenaw	4
Kalamazoo	1	Wayne	43
Kalkaska	2	Wexford	2
Kent	33		

OTHER STATES AND COUNTRIES REPRESENTED.

Connecticut	2	New Jersey	1
Florida	1	New York	26
Germany	1	North Carolina	1
Illinois	7	Ohio	15
India	1	Oklahoma	1
Indiana	6	Pennsylvania	5
Iowa	1	Russia	1
Maryland	1	Virginia	1
Massachusetts	3	West Virginia	1
Montana	1	Wisconsin	2
New Hampshire	2		

STATISTICS OF ENTERING CLASS.

	Men.	Women.	Total.
Number entering	409	113	522
Average age	20.4	20.5	20.4
Schools:			
Academy	4	1	5
Age	15	2	17
College	29	7	36
High	326	91	417
Preparatory	11	2	13
State Normal	11	6	17
State University	13	1	17
[illegible]			
Parents	188	93	281
Self	150	11	161
Parents and self	55	2	57
Others	16	7	23

CHURCH MEMBERSHIP.

	Members.	Preference	Total.
Baptist	17	24	41
Catholic	29		29
Christian	3	3	6
Christian Science		6	6
Congregational	36	30	66
Episcopal	22	12	34
Evangelical	4	2	6
Friends	1		1
Hebrew	3	6	9
Lutheran	19	5	24
Methodist Episcopal	69	82	151
Methodist Protestant		1	1
Methodist (German)	1		1
No preference			57
Presbyterian	38	28	66
Reformed	5	2	7
Unitarian	4	2	6
United Brethren	2	3	5
Universalist		6	6

SUMMARY OF STUDENTS.

	Agricultural.	Engineering.	Home Economics.	Forestry.	Veterinary.	Totals.
Graduate students	4					4
Class of '13	77	53	35	16	1	182
Class of '14	66	89	48	11	2	214
Class of '15	109	106	63	19	8	304
Class of '16	180	143	99		8	436
Class of '17	60	40	17		2	119
Special students	42	3	10	4	3	62
Special short course students	326					326
Totals	864	434	272	53	24	1,647
Deduct names repeated						4
Net total						1,643

OCCUPATION OF FATHERS OF ENTERING CLASS.

	Men.	Women.	Total.
Architect	1		1
Banker	7	5	12
Barber	1		1
Blacksmith	1		1
Carpenter	10		10
Clerk	13	2	15
Contractor	14	4	18
County and State Officers	2	1	3
Deceased	15	5	20
Dentist	1		1
Druggist	1		1
Editor		1	1
Engineer	9	3	12
Farming	133	38	171
General Manager	3	1	1
Hotel	3	1	4
Florist	1		1
Insurance	2		2
Jeweler	3		3
Laborer	10		10
Lawyer	1	3	7
Livery	1		1
Lumberman	8		8
Manufacturer	6	1	7
Mason	2		2
Mechanic	13	1	17
Merchant	42	17	59
Mining	3		3
Minister	3	5	8
Molder	1		1
Musician	1		1
Not given	22	6	28
Painter		1	1
Photographer	1		1
Physician	10	2	12
Printer		1	1
Railroad	11		11
Real Estate	8		8
Retired	11	3	14
Salesman	12	4	16
Seaman	1		1
Sexton	1		1
Stenographer	2		2
Stockman	1		1
Tailor	2	1	3
Teacher	4		4
Theatre	2		2
Undertaker		2	2
U. S. Postoffice	7	2	9

NAMES OF GRADUATING CLASS.

(Students in Agriculture are designated by "*a*;" Engineering by "*e*;" Home Economics by "*h*;" Forestry by "*f*," and Veterinary Science by "*v*.")

Name.	Post Office.	County.
Alger, Eulalia Belle, *h*	Clare	Clare.
Allen, Gleason, *e*	Comstock	Kalamazoo.
Allen, Percy Ira, *a*	Rochester	New York.
Allen, Rhea Bernice, *h*	East Lansing	Ingham.
Andrews, Francis Englebert, *e*	Grand Rapids	Kent.
Avery, Jeane P., *h*	Lansing	Ingham.
Baab, Minnie Ellen, *h*	Orville	Ohio.
Bailey, Frank Taylor, *a*	Hillsdale	Hillsdale.
Baker, Thomas Fred, *a*	Grand Haven	Ottawa.
Ball, Luie Hopkins, *h*	Grand Rapids	Kent.
Bauer, Clifford Lawrence, *e*	Clinton	Lenawee.
Bauer, Walter Ferdinand, *e*	Detroit	Wayne.
Bissell, Richard Elwood, *e*	Milford	Oakland.
Bloomquist, Fritz Theodore, *a*	Manistique	Schoolcraft.
Bowles, Herbert Rudolph, *a*	Detroit	Wayne.
Bradley, Harry Haze, *e*	Lansing	Ingham.
Brandes, Elmer Walker, *a*	Detroit	Wayne.
Brands, Ivan Eames, *e*	Corunna	Shiawassee.
Brice, Dwight Allen, *a*	Detroit	Wayne.
Brusselbach, Ruth Antoinette, *h*	Haslett	Ingham.
Campbell, Leroy Wardell, *e*	Grand Rapids	Kent.
Carey, Lafayette Charles, *a*	Charlevoix	Charlevoix.
Carstens, Carl Christopher, *a*	Michigan City	Indiana.
Chamberlin, Ralph Gerald, *e*	Grand Rapids	Kent.
Chambers, Edward George, *e*	Frankfort	Benzie.
Chapman, Carroll Barney, *e*	Rochester	Oakland.
Clawson, Mary Louise, *h*	Detroit	Wayne.
Clemens, Louise Isabel, *h*	Sebewaing	Huron.
Clothier, Hubert George, *a*	Marlette	Sanilac.
Colgan, Richard Andrew, *f*	Berwyn	Pennsylvania.
Collins, Earl Harry, *e*	Lansing	Ingham.
Cook, Gerald D., *f*	Grand Haven	Ottawa.
Corey, Walter Coombs, *a*	Fort Wayne	Indiana.
Cowing, Frank Pickering, *f*	Homewood	Illinois.
Crane, Laura Edna, *h*	Saginaw	Saginaw.
Crane, Rena, *h*	Fennville	Allegan.
Crawford, Charles Beattie, *f*	Flint	Genesee.
Cumming, William Sinclair, *e*	Sibley	Wayne.
Davidson, William Leslie, *a*	Alpena	Alpena.
Dean, Truman J., *e*	Ypsilanti	Washtenaw.
DeGlopper, Martin, *e*	Grand Haven	Ottawa.
Dennison, Homer Edward, *a*	East Lansing	Ingham.
Digby, Earl Leo, *a*	Bay City	Bay.
Dillman, Grover Cleveland, *e*	Bangor	Van Buren.
Doan, George H., *e*	Sandusky	Sanilac.
Douglas, Earl Chester, *e*	Elkhart	Indiana.
Dunn, Lancie William, *e*	Sparta	Kent.
Eddy, Alfred, *a*	Port Austin	Huron.
Ellman, Morris Crasniansky, *a*	New Haven	Connecticut.
Favorite, Nellie Grace, *h*	Huntington	Indiana.
Fields, Walter Samuel, *a*	Buffalo	New York.
Filkins, Stanley Jay, *e*	Oak Grove	Livingston.
Fletcher, John DeShon, *f*	Berrien	Berrien.
Frahm, Norman Fred, *a*	Detroit	Wayne.
Gaffney, Edward Bernard, *e*	Roscommon	Roscommon.
Gardner, Harriet Barbara, *h*	Lansing	Ingham.
Geyer, Elmer Charles, *f*	Unionville	Tuscola.
Gilson, Clair Amasa, *e*	Niles	Berrien.
Godin, Frederick Joseph, *a*	Sault Ste. Marie	Chippewa.
Goodwin, Ozias Talcott, *a*	Ionia	Ionia.
Gorenflo, Elmer Frederick, *a*	Detroit	Wayne.
Graham, Gladys Phyllis, *h*	Ithaca	Gratiot.
Gribble, William Charles, *e*	Ironwood	Gogebic.
Gridley, Norman Brown, *e*	East Lansing	Ingham.
Hack, David George, *e*	Saline	Washtenaw.
Hagerman, Deloy Lesly, *a*	Allen	Hillsdale.
Hall, Carroll Hersey, *e*	Buffalo	New York.
Hamilton, Joseph Heald, *a*	Grand Rapids	Kent.
Hammon, Dana Charles, *e*	Vermontville	Eaton.

NAMES OF GRADUATING CLASS.—*Continued.*

Name.	Post Office.	County.
Harvey, Burtwill, *e*	Utica	Macomb.
Haugh, Raymond Reck, *e*	Detroit	Wayne.
Hayes, Florence Marie, *h*	Lansing	Ingham.
Hendrickson, Arthur Howard, *a*	Grand Rapids	Kent.
Hewitt, Howard Eugene, *a*	Lansing	Ingham.
Hilbert, Joseph Victor, *e*	Woodland	Barry.
Hock, Elmer Forrest, *a*	Detroit	Wayne.
Hogan, Susie Juanita, *h*	Clinton	Lenawee.
Holland, Maurice Lawrence, *a*	Roscommon	Roscommon.
Hutchins, Lee Milo, *a*	Fennville	Allegan.
Hunn, Howard H., *a*	Parma	Jackson.
Jacklin, Harold Madison, *e*	Lansing	Ingham.
Jakway, Clara Joyce, *h*	Benton Harbor	Berrien.
Kaden, Frederick Charles, *a*	Boyne	Charlevoix.
Kanters, Lloyd McNeal, *e*	Holland	Ottawa.
Kelley, Leon Perry, *e*	Alba	Antrim.
Ketcham, Paul Dwight, *a*	South Haven	Allegan.
Kiefer, Earl Chester, *e*	Frankfort	Benzie.
Kimball, Richard Mautheno, *a*	Grand Rapids	Kent.
Klinger, Karl Mott, *a*	Delaware	Ohio.
Knickerbocker, Mamie Maude, *h*	Lansing	Ingham.
Kroodsma, Raymond Frederick, *f*	Grand Rapids	Kent.
Lamoreaux, Madge, *h*	Grand Rapids	Kent.
Langworthy, Hannah Virginia, *h*	Petoskey	Emmet.
Lardie, George Leslie, *e*	Ludington	Mason.
Lewis, Almyra Dewey, *h*	Fort Wayne	Indiana.
Loree, Martha Van Orden, *h*	East Lansing	Ingham.
Loree, Robert L., *a*	East Lansing	Ingham.
Lovelace, Edward Keets, *e*	Conklin	Ottawa.
McClintock, James Albertine, *a*	Lansing	Ingham.
McDonald, William Arthur, *f*	Owosso	Shiawassee.
McIntyre, Howard Hoke, *a*	Swissvale	Pennsylvania.
McKillop, Mary Ethel, *h*	Detroit	Wayne.
McNeil, William Thomas, *a*	Colling	Tuscola.
Macdonald, Joseph Alexander, *e*	Grand Rapids	Kent.
Mason, Arthur Charles, *a*	Saline	Washtenaw.
Mather, Dan Willard, *a*	East Lansing	Ingham.
Meyer, Earl Horton, *e*	Evart	Osceola.
Miners, Harold Freeman, *e*	Berrien	Berrien.
Mooney, Bernie Edward, *f*	Lindsey	Ohio.
Moore, Morris Homer, *e*	Traverse City	Grand Traverse.
Nason, Maud Esther, *h*	Comstock Park	Kent.
Nies, William Lavane, *e*	Holland	Ottawa.
Normington, Ruth Dorothy, *h*	Ionia	Ionia.
Olney, Albert Jackson, *a*	Reeman	Newaygo.
Olney, Clinton Beem, *a*	Reeman	Newaygo.
Osler, Harold Scott, *a*	East Lansing	Ingham.
Pailthorp, Raymond Randall, *a*	Petoskey	Emmet.
Pickford, Irvin Thomas, *a*	East Lansing	Ingham.
Powell, Hazel Ethel, *h*	Toledo	Ohio.
Prescott, Lyle Arthur, *e*	Leslie	Ingham.
Reed, Luther James, *a*	Clio	Genesee.
Reiley, Wilgert, *a*	Bellaire	Antrim.
Riblet, William Roy, *e*	Elkhart	Indiana.
Riddell, Fred Thomas, *a*	Hudsonville	Ottawa
Robey, Orsel Edwin, *e*	Okemos	Ingham.
Rosen, Robert, *a*	Detroit	Wayne.
Runner, Arthur John, *a*	Shelby	Oceana
Russell, Merl Andrew, *a*	Greenville	Montcalm.
Sackrider, Ard Thomas, *a*	Battle Creek	Calhoun.
Sandhammer, Frank, *a*	Bucyrus	Ohio.
Sayre, Donald Thomas, *a*	South Lyon	Oakland.
Schuyler, Harry A., *a*	Adrian	Lenawee.
Scriber, Lynn William, *a*	Detroit	Wayne.
Servis, Lawrence Raymond, *a*	St. Joseph	Berrien.
Shafer, Mary Sylvia, *h*	East Lansing	Ingham.
Sherman, Iva Dell, *h*	Elsie	Clinton.
Shuttleworth, Earl Harrison, *e*	Lansing	Ingham.
Sibley, Judson Standish, *f*	Pontiac	Oakland.
Simpson, Nathan Duncombe, *a*	Jackson	Jackson.

NAMES OF GRADUATING CLASS.—*Concluded.*

Name.	Post Office.	County.
Smith, Lodie Reed, *h*	Marion	Indiana.
Smoker, Roy Simon, *a*	Goshen	Indiana.
Snow, Harry Gilbert, *a*	Richland	Kalamazoo.
Stege, George William, *e*	Manistee	Manistee.
Stone, Donald Dwight, *e*	Flint	Genesee.
Thompson, Leroy Hatchel, *e*	Lansing	Ingham.
Tinker, Earl Warren, *f*	Fenton	Genesee.
Turney, Mary Emaline, *h*	Detroit	Wayne.
Vankerckhove, Joseph, *e*	Norway	Dickinson.
Vining, Keats Kendall, *a*	Lakeview	Montcalm.
Waagbo, Herman, *a*	Northport	Leelanau.
Waldron, Clara May, *h*	Tecumseh	Lenawee.
Walsh, Frederick John, *e*	Grand Haven	Ottawa.
Ward, Homer Merle, *e*	Hillsdale	Hillsdale.
Warner, Arthur Erastus, *f*	Plymouth	Wayne.
Wells, Joseph Samuel, *a*	Vassar	Tuscola.
Wendt, John Martin, *a*	Capac	St. Clair.
Westveld, Marinus, *f*	Grand Rapids	Kent.
Wheater, Henry Jay, *a*	Plainwell	Allegan.
Wileden, Lewis Alison, *e*	Ortonville	Oakland.
Wilhelm, Philip Warren, *a*	Webster Crossing	Livingston.
Wilson, Alston John, *a*	Blacklick	Ohio.
Wolf, Arthur David, *f*	Grand Rapids	Kent.
Woodin, Irving John, *a*	Owosso	Shiawassee.
Wright, Harmon Kline, *a*	Benton Harbor	Berrien.
Zikgraf, Arthur Ferdinand, *e*	Lansing	Ingham.

ADVANCED DEGREES.

Name.	Post Office.	County.
Auten, Claude Isaac, *C. E.*	Detroit	Wayne.
Bates, Erastus Newton, *M. E.*	New York	New York.
Cade, Claude Marshall, *C. E.*	Capac	St. Clair.
Carrier, Lyman M., *M. Ag.*	Blacksburg	Virginia.
Cavanagh, John Griffith, *C. E.*	Cleveland	Ohio.
Dikeman, Myron Jay, *C. E.*	Brooklyn	New York.
Foster, Floyd Ossian, *M. Ag.*	Indianapolis	Indiana.
Gilger, Mrs. Amy Vaughn, *M. H E.*	Toledo	Ohio.
Goetz, Christian Herman, *M. For.*	Columbus	Ohio.
Gurney, Dayton Alvin, *M. E.*	Washington	D. C.
Hurley, John Carleton, *M. S.*	Macedon	New York.
Ireland, Capt. Mark Lorin, *M. E.*	Fort Monroe	Virginia.
Ireland, Mrs. Irma Thompson, *M. H E.*	Fort Monroe	Virginia.
Johnson, Maurice Flower, *C. E.*	East Lansing	Ingham.
Johnson, Sidney Egbert, *C. E.*	Madison	Wisconsin.
Krentel, Calla Lillie, *M. H E.*	East Lansing	Ingham.
Northrup, Lydia Zae, *M. H E.*	East Lansing	Ingham.
Oviatt, Charles Jay, *M. S.*	Bay City	Bay.
Piper, William Eugene, *M. E.*	Detroit	Wayne.
Pokorny, Emil Charles, *M. E.*	Detroit	Wayne.
Raven, Pauline Elnora, *M. H E.*	East Lansing	Ingham.
Reed, Clarence Arthur, *M. Hort.*	Washington	D. C.
Reed, Mrs. Katherine McNaughton, *M. H E.*	Washington	D. C.
Ross, Charles Burt, *M. S.*	W. Raleigh	N. Carolina.
Sanford, Frank Hobart, *M. For.*	East Lansing	Ingham.
Severance, Howard Daniel, *C. E.*	Monterey	California.
Spencer, Louis Martin, *C. E.*	Washington	D. C.
Steele, Joseph Herbert, *C. E.*	Rapid City	South Dakota.
Svetlikoff, Konstantin N., *M. S.*	Suzran	Russia.
Thatcher, Fent Edwin N., *C. E.*	Alliance	Ohio.

REPORT OF THE DEAN OF AGRICULTURE.

To President J. L. Snyder:

The educational work of the Agricultural division continued throughout the year without any marked changes. The graduating class in agriculture, horticulture and forestry was the largest in the history of the institution including a total of 83 of which number 69 graduated in agriculture and horticulture and 14 in forestry. Nine advanced degrees were awarded, viz: 4 M. S., 2 M. Agr., 2 M. For. and 1 M. Hort.

The enrollment of freshmen has increased gradually during the past several years resulting in larger upper classes. This increase demands more and more time and effort on the part of the instructors of the departments, some of which are greatly in need of assistance particularly where laboratory work is offered to freshmen and sophomores. A spirit of good will and satisfaction seemed to pervade students of the division generally.

The following is a statement of the number of students enrolled in the Agricultural division during the year, viz:

Students enrolled during 1912-13 in Agriculture and Forestry.

Post Graduates	4
Seniors	93
Juniors	80
Sophomores	128
Freshmen	180
Sub-freshmen	60
Specials	46
	591

Special Short Course Students, Winter term 1913.

General Agriculture 1st year, eight weeks	180
General Agriculture 2nd. year, eight weeks	63
Creamery Courses first and second years including cheese makers	43
Poultry	14
Fruit	18
	318

During the legislative session of the present year the necessity for establishing a two year course in practical agriculture was urged upon the institution. As a result the following report was submitted by a committee of the faculty and was later adopted by the State Board of Agriculture, viz:

"Recommendations relative to Short Courses for the year 1913-14.

"During the college year, now about to close, five short courses were offered, viz: General Agriculture, first and second years; Creamery Management, first and second years; Cheese Making; Poultry Raising and Fruit Growing. These were all eight weeks courses except the second year Creamery Management which was six. During the development of these courses the process has been a lengthening one, the course in Fruit Growing at one time extending over but two weeks. The committee recommends that all courses other than general agriculture remain unchanged, as to time and general plan, for the present.

"Your committee also recommends that the course in general agriculture, for the coming year, be lengthened by the addition of seven weeks beginning Monday, November 3rd., 1913. The future may demand still further extension but we deem it best not to make a more radical change during the first year of the transition. We also recommend that, for a time at least, the work of this first term, November 3rd. to December 19th., be made independent, as far as possible, of the second term until the new plan shall have completely replaced the present eight weeks course.

"This would therefore make it possible to readvertise the second terms along with the other short courses after registration for the first term had taken place.

"We also recommend that the standard of entrance should not be less than completion of the eighth grade or its equivalent, and that the minimum age limit should not be less than seventeen years."

The following is an outline of the two year short course now being offered including subject designations and time allowed:

SCHEDULE OF STUDIES FOR TWO-YEAR WINTER COURSE IN AGRICULTURE.

FIRST YEAR.

First Term.	Hours.
Live Stock, Breed Types	70
English	35
Forge and Bench	70
Soil Formation	20
Farm Crops	15
Second Term.	
Study of Breeds	60
Forge and Bench	60
Veterinary Science	40
Soils	20
Farm Crops	20
Animal Feeding	40
Horticulture	20
Forestry	20

SECOND YEAR.

First Term.

Advanced Farm Crops	35
Animal Breeding	18
Advanced Soils Laboratory	35
Farm Management	18
Plant Diseases	18
English	18
Meteorology	18
Agricultural Development	18

Second Term.

Dairying	40
Farm Engineering	40
Chemistry	80
Stock Judging	40
Building Design	40
Bacteriology (Animal Diseases)	20
Entomology	20

During the year the dean of the division has been appointed to represent the college in relation to the co-operative work with the United States Department of Agriculture pertaining to "investigations relative to methods of farm management and agricultural demonstrations" which adjustment places the Department of Farm Management within the Division of Agriculture of the college.

During the latter part of the year the agricultural extension work of the college was formally organized by the State Board of Agriculture upon recommendation of the Agricultural division faculty which submitted the following resolutions which were adopted with the exception of one section.

The following resolution relating to organization of agricultural extension work was passed on May 1st., 1913, at a joint meeting of the Agricultural division faculty and Experiment Station Council, viz:

"That a department of college extension should be organized for administrative purposes and should be a part of the Agricultural division subject to the Dean of Agriculture.

"That no line of extension work should be done except by members of the college department representing that line."

The last part of this recommendation is in accord with the generally accepted idea that the triple functions of each department should be controlled by it, including everything pertaining to education, investigation and extension. This plan is desirable in order to enable the head of each department to control and direct all three lines of work, thereby harmonizing them and establishing perfect co-operation in every detail. This plan does not intend that the individual workers of each department shall participate in all three lines of work, but rather that there shall be specialists in each, though special conditions may demand participation by the individual worker in more than one line of effort. For purposes of illustration, the head of the Horticultural department would control and direct all horticultural work, including college teaching, experimentation at home and in the field, as well as the horti-

cultural extension out in the state. Some of the Horticultural department staff might be confined solely to one of these lines of effort, others to two, and, in exceptional instances some to all three.

The Department of Extension, in charge of a superintendent, should become sort of a clearing house for the entire extension movement. Such an office would be expected to organize and operate lines of work not directly connected with individual departments, or where combinations of the efforts of several departments are involved. The following are some of the specific duties for which the Superintendent of Extension should be responsible, viz:

(1) Preparation and supply of uniform forms for weekly reports.

(2) Collection and compilation of data from all sources for annual reports on extension work.

(3) Supervision of publication of all materials required by individual departments for use in extension work.

(4) Direction of one-week and all other local farmers' schools.

(5) Direction of demonstration trains necessitating speakers and exhibits from several departments. In fact, all special forms of demonstration involving more than one department should be included under this head.

(6) The responsibility for fair exhibits should rest here also.

(7) One of the most important duties of this office should consist of modest publicity work, by way of the preparation of material for publication informing the public of what is being attempted and the various ways in which aid may be procured.

"Immediate pressing needs for the development of agricultural extension work in Michigan seems to demand the addition of a few more men and the appropriation of more funds with which to extend the work. Recommendations with regard to these matters will be embodied in an accompanying communication."

An account of the extension work of the various departments is included in the individual reports. The following statements relate to three lines of extension directed from this office.

The following statement relates to the work of W. F. Raven, whose chief work is that of live stock field agent engaged in the organization of co-operative breeders' associations. In addition, however, Mr. Raven's services are called upon in a variety of ways. During the months of July and August Mr. Raven superintended the land clearing operations on the station farm at Chatham, Michigan. Sixty-five acres were rough burned, logged and reburned and seeded to a mixture of two pounds each of the following, viz: June, Mammoth, and Alsike clovers, alfalfa and four pounds of timothy per acre, which developed into a perfect stand. An additional sixty acres was rough burned and logged and piled but could not be burned again on account of exceedingly wet weather.

Mr. Raven acted as superintendent of cattle at the West Michigan State Fair, an office involving much work and the exercise of good business ability. He also assisted with the dairy cow demonstration at the State Fair at Detroit and judged the live stock at the Menominee county fair. He also had charge of the Michigan exhibit at the National Corn Exposition held at Columbia, S. C., January 18th. to February 20th.

Mr. Raven has been the means of organizing sixty-six cattle breeders' associations in twenty-nine counties. Hundreds of pure bred sires have

been procured as a result and the number of animals annually affected by this system of improvement now numbers over 25000 head. Six new co-operative associations were organized during the year in addition to five organizations where the sires are privately owned.

During the year Mr. Raven visited 408 farms owning 3220 cows, spent 57 days as local adviser, 55 days as demonstrator and 153 days in other extension work. He delivered 106 lectures, attended three one-week schools of agriculture, and directed the three weeks' trip of the demonstration train over the Duluth, South Shore and Atlantic Railroad in the Upper Peninsula.

During the year Mr. C. A. Tyler has devoted his energies largely to forestry extension work intended to stimulate an interest in the preservation and improvement of the Michigan farm woodlot. A few county woodlot improvement associations have been organized and some co-operative experimental plantings made. Mr. Tyler has given more or less time to farmers' institute work, lecturing at one-week schools, demonstration trains and a number of other phases of effort as well.

About June 1st, Mr. Leo M. Geismar, extension representative of the college for the Upper Peninsula, gave up his work to become county agricultural agent for Houghton county. During the year or more Mr. Geismar acted as extension worker, he organized a large number of corn, potato, alfalfa and fruit growers' clubs. It is planned to extend this work as rapidly as possible.

R. S. SHAW,
Dean of Agriculture.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF HORTICULTURE AND LANDSCAPE GARDENING.

To the President:

Sir—I herewith submit the following report of the Department of Horticulture and Landscape Gardening for the year ending June 30, 1913:

It is a pleasure to report that no change has occurred in the personnel of the department. Where all the members of a department can be retained for several years, the work can be made to progress more rapidly than where changes are frequent.

The instruction work has been given during this year as outlined in the college catalogue and may be here briefly summarized:

Fall Term.

Class.	Subject.	No. of course.	Hours per week each student.	Number of students enrolled.
Soph. Ag.	[1]Fruit Growing	2	6	133
Junior Ag.	Pomology	4	7	16
Senior Ag.	Plant Breeding	7	7	46
Senior Ag.	Seminar	10 a	1	46
Senior Ag.	Advanced Pomology	11 a	6	39
Senior Ag.	Advanced Landscape Gardening	12 a	6	6
Junior and Senior Women	[1]Landscape Gardening and Floriculture	14	7	27

Winter Term.

Class.	Subject.	No. of course.	Hours per week each student.	Number of students enrolled.
Soph. Ag	Plant Propagation	3	4	123
Junior Ag	Greenhouse Industry	5	7	38
Senior Ag	Evolution of Cultivated Plants	8	5	42
Senior Ag	Seminar	10 b	1	43
Senior Ag	Adv. Pomology	11 b	6	37
Senior Ag	Adv. Landscape Gardening	12 b	6	6

Spring Term.

Class.	Subject.	No. of course.	Hours per week each student.	Number of students enrolled.
Sub-Fresh	Vegetable Gardening	1	6	49
Junior Ag	Landscape Gardening	6	7	42
Senior Ags	Experimental Hort	9	10	40
Senior Ags	Seminar	10 c	1	40
Senior Ags	Adv. Pomology	11 c	6	34
Senior Ags	Adv. Landscape Gardening	12 c	6	6
Junior and Senior Women	Plant Propagation and Vegetable Gardening	13	7	27

The courses for sub-freshmen and freshmen are required of all agricultural students and all courses offered in the junior and senior year are optional or elective.

The greatest need of the department at this time is additional room, both in the laboratory and greenhouse. This laboratory was built just twenty-five years ago and has never been enlarged; the greenhouses were built twenty-one years ago and never enlarged. Any comparison that could be made between this equipment and conditions at the college at the present time would be unnecessary. An entirely new outfit of buildings must be provided very soon if it is desired to maintain the work in horticulture at this college in a reasonable relation to its importance as an industry in Michigan.

The extension work has grown so much that it is an impossibility for the one man to satisfy the demands for profitable meetings and requests for instruction on better methods of orcharding. The entire time of another man for this work is much needed.

The method of doing this demonstration work has been the same as in the preceding years. Neighborhood meetings are arranged and widely announced by large posters and notices sent in advance to the local newspapers. At the appointed time, the people who are interested meet in the orchard selected for the demonstration and after a talk intended to explain the reason for doing the work, the way to do it is shown and made clear to every person present. These demonstration meetings are planned to come at a time when the subject under discussion is timely and of the most interest in the community. Where possible, they are given in a series, beginning with pruning and ending with packing.

The short course in fruit growing was very successful. This year it was given in six weeks followed by two weeks of work in vegetable and truck crop production. A number of the students who were registered

for fruit growing remained for the vegetable work and a few new students came especially for it, but another year it is planned to make the fruit course eight weeks and include the work in vegetables as the demand may seem to indicate.

The "Fruit Show" was held this year as in the past four years in January. It has outgrown any space in the Horticultural Laboratory and this year, through the courtesy of Dean Shaw, one-half of the pavilion of the Agricultural Building was used. This show has always been arranged and managed by horticultural students and each year seems to be more complete and interesting.

Horticultural meetings and Farmers' Institutes have been attended by members of the department to the usual number. Extensive exhibits of objects of horticultural interest were shown at the Michigan State Fair at Detroit, the West Michigan State Fair at Grand Rapids and the Second Land and Apple Show at Grand Rapids in November. These exhibits demand a very large amount of time to prepare, pack and set up in addition to the time of an attendant who must be on duty for a long day, and the expense is quite heavy but they bring the horticultural work of the college to many people.

It is again a pleasure to report that a spirit of loyalty and co-operation among all the members of the department continues to exist and that the work of Professor C. P. Halligan, Instructors Thomas Gunson, G. W. Hood, Field Agent O. K. White and Foreman A. H. Davis has been very satisfactory.

Respectfully submitted,
H. J. EUSTACE,
Professor of Horticulture.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF DAIRY HUSBANDRY.

President J. L. Snyder:

The following is submitted as the report of the Department of Dairy Husbandry for the college year just closed:

The volume of work cared for during the past year is considerably greater than that of any of its predecessors. An abbreviated statement of the subjects taught, and the numbers enrolled in each follows.

REGULAR COLLEGE COURSES.

Animal Husbandry I	204
" " II	43
" " III	43
" " V	28
Dairy Husbandry I	125
" " II	15
" " III	8
" " IV	11

SPECIAL WINTER COURSES.

General Agriculture, 1st year	190
" " 2d year	63
" " 2d year	60
First year Creamery	10
Second year Creamery	2

In Animal Husbandry I, II and V this department did only the work relating to dairy cattle.

During the early part of the fall term a judging team was made ready for the National Dairy Show. The preliminary training was given to about a dozen men. From this number three were chosen to compete in the name of this college at the contest. They were, L. J. Reed, G. E. Piper, J. H. Hamilton. Thirteen other states entered teams. As a team our men took sixth place. In the individual winnings L. J. Reed was awarded the scholarship offered by the American Jersey Cattle Club for best work in judging the Jersey classes.

At the beginning of this year we made a strenuous effort to purchase enough raw material to adequately provide for the several classes in Dairy Manufactures, and at the same time to so apportion those materials as to manufactured products and markets that sufficient revenue should be derived from materials sold to cover all expenses for the same. With the conditions under which our men have been obliged to work in the old building we feel reasonably well satisfied with the progress made in this direction. Upon the completion of the commodious and well appointed building now under erection we hope to be able to place our entire scheme of Dairy Manufactures upon a more permanent and stable foundation.

In all that has been attempted we have had the earnest co-operation and faithful support of C. E. Newlander, H. E. Dennison, and O. A. Jamison as regular instructors, and of Simon Hagedorn and Charles H. Dear during the special winter courses.

Respectfully submitted,
A. C. ANDERSON,
Professor of Dairy Husbandry.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF ANIMAL HUSBANDRY.

To the President, Michigan Agricultural College:

Dear Sir—I have the honor to submit herewith the report of the Department of Animal Husbandry for the year ending June 30, 1913.

During the Fall Term, 1912, instruction was given to 204 freshmen in Animal Husbandry I. This class was divided into two sections which we had hoped to further divide for the practical work in the pavilion, but owing to the increased correspondence and personal attention required by the live stock equipment it was impossible for both members of the department to devote their time to this work.

In Animal Husbandry II, 43 junior agricultural students were en-

rolled. In Animal Husbandry V, optional with seniors, 28 men were instructed.

According to faculty ruling, all required technical work must be given in the afternoon making it necessary to instruct both of the above classes at the same hour. This arrangement makes it difficult to give the upper classmen the grade of work they should receive, as it is impossible to divide either of these classes or have more than one instructor with them. In justice to the students one of these classes, preferably the junior class, should be scheduled for the last two periods in the forenoon.

During the first eight weeks of the winter term the twenty seniors enrolled in Animal Husbandry VI were instructed by Prof. Norton, who rendered valuable assistance during the Short Course. Better facilities are urgently needed for this work. The building at present in use would, with a few needed improvements, serve very well as an abattoir, but as a laboratory for meat cutting it is not large enough, nor could facilities for handling and holding meat until the classes have made a study of it, be provided. Abundant space for the proper carrying on of this work was provided for in the new Agricultural Building, but has not been equipped.

The real test of a good meat animal is its ability to produce a good carcass, and until facilities are provided that will permit the classes to judge the carcasses on the hooks and later on the block as well as on foot, the work will be under a serious handicap.

The 180 men enrolled in the first year short course work displayed a lively interest in the work, but, as with the freshmen class, the sections are too large. Sixty-three men were back for the second year work. More time should be given this class for judging work, as 32 hours is not sufficient time for the judging of beef cattle, dairy cattle, horses, sheep and swine.

With only two men in the department the instruction work requires so much time that it is impossible to properly supervise experimental work, for which there is urgent need.

Another serious handicap is the lack of storage room for grain, making it necessary to buy feed in small amounts throughout the year, which materially increases the cost of maintaining the live stock equipment.

In September, 1912, an exhibit of live stock was made at the Cadillac and Traverse City fairs. At both fairs a lively interest was displayed by the farmers visiting the exhibit, who went away enthused with the idea of raising more and better live stock.

During the past year Mr. D. A. Spencer has rendered valuable assistance.

Respectfully submitted,

GEO. A. BROWN,

Instructor in Charge.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF SOILS.

President J. L. Snyder:

Dear Sir—The college year just closed has brought no unusual experiences to the Soils department to report. The enrollments in classes were larger than in any previous year, as would be expected from the healthy growth of the institution. Instruction has been given to over seven hundred and twenty-five students.

I reported a year ago that the installment of equipment for the teaching of soils is a matter of development and hence rather slow. I am glad to report that it has been possible during the year to increase our equipment very materially, and hence to do more for our students in the way of laboratory instruction. At the same time we have been enlarging and improving our courses and our methods of instruction.

The most serious difficulty in giving instruction has resulted from a lack of help. It has been necessary at times for one teacher to attempt to direct as many as forty-five men in the laboratory. Under such a condition it is very difficult indeed, to get desirable results. During the winter term Mr. E. I. Holmes was employed to assist in laboratory work. Mr. Holmes' services were very acceptable and made it possible to materially increase the efficiency of our laboratory work. The additional help provided for by recent action of the Board should further improve conditions in this direction.

On June 5, 6 and 7 thirty-one members of the class in Farm Management (Soils 3a) visited a number of typical Michigan farms to make a study of methods. This proved the most profitable trip yet made by members of the Farm Management class. Thanks are due the managers and owners of these farms, not only for the time given in describing the operation and equipment of their farms, but also for the hospitality extended. The information obtained on this trip and the opportunities given for comparison and criticism were greatly appreciated by the students making the trip.

The amount of extension work done this year by the department is perhaps under that of previous years, chiefly because of the increasing amount of work of the department. Numerous requests for help have been "turned down" because it was impossible to meet them. The head of the department has given something over thirty days actual time to extension work, while Mr. Spurway has given more than half that amount of time to such work.

Very respectfully,
JOS. A. JEFFERY,
Professor of Soils and Soil Physics.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF FARM CROPS.

President J. L. Snyder:

Dear Sir—I wish to submit the following report of the Department of Farm Crops for the year ending June 30th, 1913:

The several courses offered by the department have been given practically as outlined in the catalogue, but these have been somewhat modified and strengthened from year to year. It is desired to place the instruction of the department on as definite a pedagogical basis as possible and to make the instruction as practical as possible. Some additional equipment and a large number of charts and illustrations have been acquired.

The number of students to whom instruction was given in the several courses was as follows:

Farm Crops I. Freshmen	197
Farm Crops II. Sophomores	150
Farm Crops III. Seniors	15
Farm Crops IV. Seniors	18
Farm Crops V. Seniors	27
First Year Short Course	180
Second Year Short Course	64
Total	651

Mr. C. L. Coffeen has had charge of the freshman and sophomore classes and has assisted in the laboratory work of Farm Crops III, and the second year Short Course classes. Mr. F. A. Spragg has had charge of Farm Crops V. I have had charge of the remaining classes. Mr. M. A. Russell and A. T. Sackrider acted as student assistants in the laboratory work of the second year Short Course classes.

EXTENSION WORK.

The department has continued the distribution of the pure strains of the more important crops developed by Mr. Spragg. This work has also included the testing of several commercial varieties of corn and a few beans and oats which have seemed especially promising. The number of co-operators and the number of lots of each crop are given below:

	No. Cooperators.	No. Lots of Seed.
Alfalfa	5	25
Beans	8	25
Soy beans	37	37
Corn	101	157
Barley	3	5
Oats	51	64
Wheat	29	51
Rye	9	22

Eight co-operative fertilizer experiments are being conducted. Several co-operators are engaged in the breeding of crops, conducting green manure tests, and other experiments. This work is being carried on principally with the members of the Michigan Experiment Association and the Short Course students. It is gratifying that on the whole the seeds developed on the Experiment Station have given better results than the seeds from other sources.

The other lines of extension work have been carried on much the same as in previous years. The total number of alfalfa clubs formed in the Lower Peninsula to date is 115. All the new clubs have been visited by the field agent or other representatives of the department with the exception of a few organized just at the close of the fiscal year. The field agent attended 21 institutes, spent 26 days in a crop improvement campaign and several weeks in looking after co-operative experimental work. Various members of the department have acted as judges at 17 corn shows, assisted in 4 county alfalfa campaigns, made exhibits at 3 Michigan fairs and the National Corn Exposition, delivered lectures at one week courses in agriculture, and met about 30 engagements with granges, farmers' clubs, experiment associations, etc., outside of the regular work of the field agent. Some time has also been spent in studying crop conditions and securing further data in regard to the culture of Michigan crops.

Most of the alfalfa extension work as well as a considerable portion of the other extension work of the department has been very efficiently handled by the field agent, Mr. A. R. Potts.

Respectfully submitted,
V. M. SHOESMITH,
Professor of Farm Crops.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF POULTRY HUSBANDRY.

President J. L. Snyder:

Sir—I have the honor to submit the following report of the Department of Poultry Husbandry for the year ending June 30th, 1913.

The policy of the department has been to outline work of such nature that the students taking courses in Poultry Husbandry would do as much research and practical work as possible which, combined with the series of lectures, would enable them to better conduct this branch of farm management in their own interests or to assume commercial obligations for others.

Seven agricultural students completed the senior work for the fall and winter terms and six completed the spring term; forty-five students attended the series of lectures for juniors in the spring term and twenty took the special eight weeks Short Course in Poultry Husbandry.

From February 10th to 15th inclusive, a Poultry Week was held at the college during which a very excellent program was carried out as follows:

MONDAY.

Evening—

Meeting of M. A. C. Poultry Association, Agricultural Building.
Hearty welcome extended to visitors.
Good program along poultry lines.

TUESDAY.

Morning—

Welcome....................................Pres. J. L. Snyder
"Poultry work at Michigan Agricultural College,".....J. O. Linton
"Poultry Feeding,"..
Prof. W. R. Graham, Ontario Agricultural College, Guelph, Ont.
"My Own Experience in Poultry Raising,"..................
.......I. A. Freeman, A. P. A. Lecture Bureau, Fenton, Mich.

Afternoon—

"Importance of Constitutional Vigor in Building up and Improving the Flock,".........Mr. Chas. J. Maywood, Hastings, Michigan
"Feeding for Egg Production."

Evening—

Entertainment ....Selected
"Some Cold Facts and Other Factors Regarding the Improvement of the Farm Egg,"......................................
J. E. Waggoner, Mason, Mich., Sec. Mich. Poultry, Butter and Egg Shippers' Assn.

WEDNESDAY.

Morning—

"Poultry Housing,"...............................J. O. Linton
"Poultry Breeding," ....Prof. Graham
"Commercial Poultry Raising as We Find it Today,"..I. A. Freeman

Afternoon—

"How to Read the Poultry Press,"..C. E. Walter, Kalamazoo, Mich.
"Poultry Pleasures of the Farmer's Wife," ....
.........................Mrs. E. J. Creyts, Lansing, Michigan.

Evening—

"Relation of Weather to Poultry Interests,"..................
...D. A. Seeley, U. S. Weather Bureau, East Lansing, Michigan
"Marketing,"......................................Prof. Graham

THURSDAY.

Morning—

"Poultry Parasites,"..............................J. O. Linton
"General Care of Poultry,".........................Prof. Graham
"The Importance of Better Organization of Michigan Poultry Culture,"...I. A. Freeman

Afternoon—

"Reasons for Success,"...........................C. J. Burkman

Evening—
Banquet..Higgs Cafe

FRIDAY.

Morning—
"Fancy Poultry,"..............................Earl Hemmingway
"General Management,"..........................Prof. Graham
"Poultry Diseases,"........................Doctor Ward Giltner

Afternoon—
"Chalk Talk—Standard Types,"............................
Franklane L. Sewell, Artist for American Poultry Association
"Poultry in the Schools,"............Prof. W. H. French, M. A. C.

Evening—
"Progress of the Wyandotte,"........................F. L. Sewell

Also a series of poultry lectures was given the 160 general Short Course students.

The Poultry Show was the biggest and best ever held at the college, there being more than five hundred birds in competition all owned by exhibitors outside of the college department. Judges Tucker and Wise were very willing to help the students by suggestions and information regarding types of birds and the judging. The show was attended by large crowds each day and evening.

The Battle Creek Poultry Association was very generous in the loan of their new uniform wire cooping which showed the exhibits to excellent advantage.

A fine banquet, well attended by the fanciers, their wives and friends, was served at Higgs Cafe, Thursday evening.

During the year the department was represented in seventeen Michigan cities and towns where twenty-six lectures were given to audiences averaging one hundred to the meeting. Besides these the department was also represented on a special Agricultural Demonstration Train over the D. S. S. & A. R. R., in Upper Michigan where lectures were given to about 12,000 people and a fine exhibit was carried in one coach for demonstration.

Ten poultry shows and fairs were visited, five of which were judged by department representatives.

In December several students and the department head attended the Ontario Provincial Winter Fair in Guelph, Canada, and visited the Ontario Agricultural College where many suggestions were secured and information gathered regarding poultry work.

It has been a pleasure to co-operate with the Michigan Poultry, Butter and Egg Shippers' Association, the State Branch of the American Poultry Association and the Michigan State Poultry Breeders' Association, to which later organization the writer was elected Vice President for the ensuing year.

The department was also honored by representation for talk regarding use of milk for poultry feeding, at the meeting of the State Dairy and Creamerymen's Ass'n. in Saginaw.

A small amount of institute work was done in co-operation with

Supt. L. R. Taft and several trips for investigation and suggestion were made to various parts of the state.

In connection with the Bacteriological department there has been considerable work done toward the diagnosing and treating of poultry diseases, much of which has proved very beneficial to state patrons.

The students taking work made several trips to commercial poultry plants and the department is greatly indebted to the owners of local and near by plants for their kindness and co-operation in its behalf.

Mr. Lewis Fuller of East Lansing very ably conducted the Short Course teaching in January and February for which he deserves much credit.

Messrs. C. C. Ingham and R. Wiggins have been faithful to the department in caring for the work at the college poultry farm and through their efforts the plant is in excellent condition for good results during the coming season.

The demands for information and help along poultry lines, especially dealing with lecture and extension work are continually increasing and numbers of calls have been refused because of a lack of sufficient staff in the department.

Very truly yours,
J. O. LINTON.
Instructor in Poultry Husbandry in Charge.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF FARM MECHANICS.

President J. L. Snyder:

Dear Sir—I have the honor to submit the report of the Department of Farm Mechanics for the year 1912-13:

I am indebted to Mr. Watt and Mr. Fogle of the regular instructional force for their interest in improving the work of the department and in the standard of work required in the shops. I should also like to take this opportunity to express appreciation of the work of Mr. Houghtalling and Mr. Filkins who assisted in the laboratory work given in the Short Courses.

Besides the two courses in shop, three courses of instruction are being offered by the department. This year the course in Farm Construction was offered for the second time. The course was outlined to familiarize the student with the simpler types of construction and equipment such as gates, fences, water tanks, and other small construction, as well as the plans and requirements of the larger farm structures. Building materials and their uses were discussed. Laboratory work consisted of drawing, and work in the cement laboratory. Altogether this work has proven of interest and value to the student and seems well worth a place in the curriculum. Along this same line the department has been called upon to answer many inquiries relating to building construction and to design a few structures where the nature of the case seemed to demand it. This latter phase of the work is deserving of more time and careful attention than we have been able to give in some cases.

The increasing use of mechanical power on the farm has made the course in Power Machinery of interest. Mention is due of manufacturers of power machinery who have loaned to the department, unconditionally, apparatus for demonstration and instructional purposes. Through their support we have been able to carry on the laboratory work without great outlay for equipment, much of which would soon become obsolete from a practical standpoint if purchased and installed permanently.

The work in Farm Machinery has been strengthened very materially by separating it from the course in Power Machinery. The department now has a fairly representative exhibition of seeding, tillage, and harvesting machines which have been loaned to the department. Through the courtesy of the Farm Superintendent a number of field trials were made with implements in use at the spring season. One deterrent to practical instruction in this work lies in the fact that much of the machinery cannot be operated under field conditions. Future efforts of the department should be extended in the direction of more extensive use and tests of the machines in the field.

During the year considerable thought has been given to problems needing experimental investigation. There is also much information which should be collected and classified and put into form accessible by those to whom it will be especially useful. Among many practical problems needing investigation may be named: farm water supply and sewage disposal, the silo, cold storage, farm lighting, data on barns and ventilation, uses of cement, power requirements of farm machinery, application of mechanical power to field operations, designs of typical farm structures, power for domestic uses, drain tile, and irrigation. Many of these problems can best be worked out in co-operation with the other departments of the college.

Respectfully submitted,

H. H. MUSSELMAN,

Instructor in Farm Mechanics in Charge.

East Lansing, Mich., June 30, 1913.

REPORT OF DEPARTMENT OF FORESTRY.

Dr. J. L. Snyder, Michigan Agricultural College:

Dear Sir—I have the honor to submit the following report for the Department of Forestry.

The work of the year has been somewhat broken owing to the absence from the department for a portion of the time, of Professor J. Fred Baker who is studying European Forestry on leave for eighteen months and also from the leave of absence granted to Instructor W. Irving Gilson for the last six months of the year. During the absence of the above mentioned members of the force, the teaching work was handled by Instructor S. V. Klem, newly elected at the beginning of the spring term, and the writer. The schedule of instruction with hours, number of students enrolled and courses follows herewith:

Subject.	No. of course.	Class.	No. of students enrolled.	No. hours per week for each student.	In charge of.
Forest Technology	Forestry 9	Senior	16	10	J. F. Baker.
Silviculture	Forestry 5 a	Junior	12	6	F. H. Sanford.
Mensuration	Forestry 3 a	Junior	12	4	F. H. Sanford.
Lumbering	Forestry 10	Senior	16	3	W. I. Gilson.
Forest Law	Forestry 11	Senior	16	2	W. I. Gilson.
Forest Products	Forestry 12	Senior	14	3	J. F. Baker.
Seminar	Forestry 14	Senior	14	5	J. F. Baker.
Dendrology	Forestry 2	Sophomore	24	3	F. H. Sanford.
Forest Protection	Forestry 6	Junior	22	6	F. H. Sanford.
Forest Protection	Forestry 13	Seniors	11	3	F. H. Sanford.
Short Course				1 week	F. H. Sanford.
Forest Management	Forestry 13	Seniors	14	4	W. I. Gilson.
Forest Physiography	Forestry 7	Junior	22	2	W. I. Gilson.
Dendrology	Forestry 2 a	Sophomore	15	8	F. H. Sanford.
Silviculture	Forestry 5 b	Junior	12	6	F. H. Sanford.
Forest Investigations	Forestry 16	Senior	15	10	F. H. Sanford.
Forest Working Plans	Forestry 15	Senior	16	5	S. V. Klem.
Forest Geography	Forestry 8	Junior	12	2	S. V. Klem.
Introduction to Forestry	Forestry 1		155	6	S. V. Klem.

During the spring term of the year 1913, special student assistance was given, in the handling of the large laboratory sections of sophomore Dendrology and agricultural freshman Forestry, by M. Westveld, R. S. Kroodsma, P. B. Haines and J. S. Johnson, whose work was especially helpful in the management of the great number of men working out of doors.

Fourteen members of the senior class in Forestry were graduated at the Commencement on June 24th.

The 1913 summer school arrangements were completed and the site granted by the R. Hanson & Sons lumber company of Grayling, Michigan. The Summer Camp was located on the holdings of this company in Cheboygan county and it is with great pleasure that I acknowledge the courtesy and cordial treatment accorded the school by all the members of the company. The corps of instructors with courses given by each and special lecturers are as follows:

Mensuration............................S. V. Klem.
Engineering...........................W. B. Wendt.
Entomology.........................Dr. G. D. Shafer.
Field Methods.........................W. I. Gilson.
Silviculture.........................F. H. Sanford.

Special lectures:

Bird Life.......................Prof. W. B. Barrows.
Soil Formation....................Mr. R. C. Allen.
Camp Sanitation and Emergencies...............
..........................Dr. D. M. Nottingham.

The summer term opened June 23rd and closed August 9th. The work was marked by a splendid spirit of co-operation and goodwill among both teachers and students, which made the work especially pleasant and profitable to all.

Extension. Aside from the schedule of regular class work, consider-

able time was spent by the teaching force in extension work of various kinds in different parts of the state where aid was asked regarding the establishment of plantations, windbreaks and shelter belts and other phases of forestry and woodlot work. Special investigation of woodlot conditions in three townships of the state was carried on during the summer of 1912 by the writer with the aid of two senior assistants, viz: M. Westveld and R. S. Kroodsma whose conscientious efforts deserve special mention.

Nursery Operations.—The Forest Nursery maintained by the department has been handled with the same attention and care as formerly reported. The financial standing of the work is as follows:

Estimated value of stock on hand.........	$4,639.28
Total receipts from stock, 1913............	712.62
Number of coniferous seedlings and transplants sent out for planting............	62,591
Number of hardwood seedlings and transplants sent out for planting............	35,272
Total stock shipped......................	97,863

For the encouragement of rural school planting and as a means to assist in raising the interest among the children of the rural schools of Michigan, 1137 trees of different sizes, were gratuitously distributed for this purpose.

I wish to add a word of high commendation to the capable work of the following who compose the personnel of the department: Instructor S. V. Klem, Instructor W. I. Gilson, Miss Nellie Strudley, clerk, and Mr. C. B. Baker, nursery foreman. Their loyal co-operation has made it possible to report the close of a strenuous but successful year.

F. H. SANFORD,
Acting Professor of Forestry.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF AGRICULTURAL EDUCATION.

To the President:

Dear Sir—I herewith submit a brief report of my labors during the collegiate year ending June 24th:

1. I have taught the pedagogical subjects leading to teachers' certificates to both the men and the women. I have had thirty-five women and seventy men in class. Nearly all the women have secured positions to teach for next year, and twenty of the men who were graduated in agriculture have secured positions to teach agriculture during the ensuing year. Several others of the men have secured supervising positions. I have taught fifteen hours each week during the year.

2. During the past year we have had twenty high schools giving courses in agriculture taught by graduates of this institution. To this number we shall add ten new schools the ensuing year, making

thirty in all. The course of study for the high school is a four unit course, parallel to the course in science. It is an elective in the high school, and we find that from ten to fifty per cent of the boys in the high school elect the agricultural course. The largest number of students in agriculture we have at Hillsdale. It is not too much to say that the effect of introducing the agricultural courses is more far-reaching than simply the teaching of agriculture. We find that it has an inspiring and a steadying effect upon all of the work in the high school; and on the practical side we find that it is turning hundreds of young men toward agriculture who, when they entered the high school, had no intention of pursuing that vocation. This is one of the most valuable features of the agricultural instruction.

3. In connection with the high schools, we organized during the year for week short courses for the farmers of the communities. We had eighteen schools of that kind, or eighteen weeks' work. The instruction was given by Mr. Nye, Mr. Raven, Mr. Tyler, Mr. Brody of Three Rivers, and several other members of the local faculty. This form of work has given great satisfaction to the farmers, and is of immense value to the local high school. The number of farmers attending in these schools ranged from the smallest at twenty, to the largest number at one hundred and fifty. The average number attending would be about seventy-five.

4. During the spring we have begun the organization of boys' and girls' clubs in connection with rural schools. This is a new departure and we have tried only to begin the organization. We have thirty such clubs well organized, with the boys and girls working at projects on which they will make reports next fall. We have published a pamphlet of instructions and projects which has been distributed through the several counties of the state. We seek in this work to make it a back ground for agricultural instruction in the rural schools.

5. The College Extension Reading Course has been reasonably successful during the year. We have had about one hundred actual readers. The press of work in other lines has prevented our giving special and proper attention to this phase of extension work. I consider it important, and hope that in the future we may be able to give it more attention.

6. My assistant, Mr. Nye, has been employed in visiting and supervising the work done in the high schools, with the organization of boys' and girls' clubs, and as instructor in the farmers' short courses and institute work. Mr. Nye has shown himself to be a valuable assistant. His work has been exceedingly satisfactory to the people with whom he has labored and to myself. I regret very much that we are unable to retain him for another year.

7. Publications. During the past year we have published a bulletin report of twenty-four pages, on agriculture in secondary schools. In this we outlined very carefully the work that had been done during the year, and illustrated the same with cuts showing the work of the different classes. This publication was furnished to all the high schools of the state, and several hundred copies have been sent outside of the state on request.

The next publication was Bulletin 44, consisting of an outline for agricultural work in rural schools, followed by a series of simple ex-

periments and demonstrations both for indoor work and outdoor work, in order that the teachers in the rural schools might have something definite to present to the children. We prepared this bulletin at the request of Hon. L. L. Wright, State Superintendent, and the same was published by his department and distributed to all the rural schools of the state. We have had many complimentary letters from rural teachers and county commissioners concerning this bulletin. We may say that in practically all of the rural schools of the state something of the elements of agriculture has been taught during the past year. In many of the schools good use has been made of the elementary text book in the 7th and 8th grades. The aim of this instruction is mainly to interest children in agricultural work, and to teach them a respect for the business of their fathers.

A third bulletin, Bulletin No. 10, was prepared, dealing with the organization and development of boys' and girls' clubs, under the general title "Junior Agricultural Association of Michigan."

8. In addition to visiting the high schools where agriculture is taught I have visited some fifty other schools and conferred with the superintendents and boards of education in regard to introducing agriculture into the high school courses. We have also been called upon to give addresses before other high schools on the subject of agricultural education. My assistant, Mr. Nye, has helped me very materially in this matter of visitation.

9. I have conducted or assisted in ten different teachers' institutes in the state during the year. This gave me an excellent opportunity to present the subject of both elementary and secondary agriculture before considerable bodies of teachers. The discussions were mainly along the line of elementary agriculture, and I feel that this work gives me a special opportunity to keep in touch with both the rural schools and the high schools.

10. The registration and location of teachers prepared in this institution requires considerable time and a very large amount of correspondence. We had thirty graduates from the Home Economics course, nearly every one of whom desired to teach, and we have already secured places for all but eight. Many of the young women do not care to teach domestic science and art, but prefer other high school positions. As stated before in this report, twenty men have accepted places to teach. Two of these young men, Mr. Cowing and Mr. Hamilton, go to Minnesota; Mr. McDonald goes to Syracuse University; Mr. Smith and Mr. Sayre have accepted positions as teachers in the Philippines, and the rest of the young men will be employed in Michigan.

11. On April 25th the State Association for the Advancement of Agricultural Teaching met in room 109 of the Agricultural Building. This was the largest meeting yet held by this Society. The purpose of the meeting was to give an opportunity to the men teaching agriculture to get together and discuss their special problems, and also to present some of the larger problems yet to be solved in connection with the subject of agricultural education. We were very fortunate in securing Professor K. L. Hatch, of the University of Wisconsin, for an address on the subject of agricultural education. The attendance at this meeting included a large number of village and city superintendents as well as the teachers of agriculture and the members of our class

in agricultural pedagogy, who were preparing to teach. Delegates were elected to the National Society for the Advancement of Agricultural Teaching, which will meet in Washington, next November.

12. Mr. Robert Loree had charge of the employment agency for the students during the fall and winter terms, and on his resignation at the opening of the spring term the committee in charge, consisting of Professor F. S. Kedzie and myself, selected Mr. F. B. Post, a junior, to have charge of this work. Mr. Loree had been exceedingly faithful and successful in providing remunerative work for students, and Mr. Post, through his energy and activity very largely increased the scope of the work. Something over two hundred students have been assisted in this way during the collegiate year just past. All this was done at very small expense to the college, and we are sure that it was a very satisfactory work for the student body.

It is not proper here to make comparisons with similar work done in other states, but I believe that we are well abreast of the times in the matter of secondary agriculture, and that our plan of work is the proper one to pursue. The State of Michigan does not give any subsidy, or state aid, to high schools teaching industrial courses, and for this reason the work will progress slowly. Other states are giving heavy subsidies for such work, with the result that there is a large demand for instructors and supervisors. Many of the men who have graduated here have gone to other states, as we have indicated, to enter upon this phase of agricultural instruction. But notwithstanding the fact that we have no state aid our people have been very cordial in their support, and the work has gone forward as rapidly as it ought for the best safety and benefit. Vocational instruction will be valuable if it is done sanely and conservatively.

Respectfully submitted,
WALTER H. FRENCH,
Professor of Agricultural Education.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF FARM MANAGEMENT FIELD-STUDIES AND DEMONSTRATIONS.

President J. L. Snyder:

Dear Sir—In submitting the initial report of the Department of Farm Management Field-Studies and Demonstrations, it seems advisable to include a brief outline of the plans of organization. The activities of the department are co-operatively conducted by the college and the United States Department of Agriculture. In the development and execution of the plans, these institutions have deemed it advisable to have a state leader, district supervisors and county agriculturists.

The state leader, employed by both institutions and a representative of both, has general supervision of the work. I assumed my duties in the department October 28, 1912. The two principal phases of the work are: (1) farm-management investigations; and (2) agricultural extension activities with the county as the unit of organization and administration. In the phase of the work first mentioned, em-

phasis is placed upon the study of the farm as a unit and its inter-relation with the community in the agricultural development of both. In developing the plans for the second phase of the work, an effort was made to become acquainted with the extension methods and activities of the college and the United States Department of Agriculture with a view to correlating the work of this department with that of the other departments of the college and the Government.

The state has been divided into districts, comprising ten to twelve counties, and district supervisors have been appointed in three districts. They are as follows:

District.	Supervisor.	Date of Beginning Work.
North Western	M. J. Thompson*	April 1, 1912.
North Western	J. F. Zimmer	June 2, 1913.
South Central	H. F. Williams	Sept. 26, 1912.
North Central	C. P. Reed	Nov. 1, 1912.

The functions of the district supervisors are chiefly of an investigational character, such as studies in the cost of production of crops, animals, and animal products; making farm surveys to determine the most profitable types of farming in each locality; investigations of the markets and methods of marketing farm products in their districts; making preliminary surveys of the agricultural conditions of counties preparatory to the location of a county agriculturist and assisting in the direction of the work of the county agriculturists in their district.

The county agriculturists are co-operatively selected by the counties, the college and the United States Department of Agriculture. Both by correspondence and by meetings held in the counties, the plans of organization and methods of work have been explained. Numerous inquiries have been received. Requests for information in regard to the work or for assistance in organizing it and securing a county agriculturist have come from about sixty counties of the state. In the explanation of the work and in its organization in the various counties, I have addressed 117 meetings with a total estimated attendance of 15,735. Twelve counties have organized, raised funds and secured agriculturists. These are as follows:

County.	Agriculturist.	Date of Beginning Work.
Allegan	C. B. Cook	Mar. 1, 1913.
St. Clair	L. V. Crandall	Mar. 1, 1913.
Iron	R. G. Hoopingarner	Sept. 1, 1912.
Saginaw	Earl P. Robinson	April 1, 1913.
Kent	J. H. Skinner	Sept. 16, 1912.
Alpena, Presque Isle & Montmorency	H. G. Smith	July 1, 1912.
Kalamazoo	Jason Woodman	Nov. 1, 1912.
Branch	Julius W. Chapin	April 1, 1913.
Genesee	Ward H. Parker	April 1, 1913.
Newaygo	H. B. Blandford	June 10, 1913.
Houghton	Leo M. Geismar	June 1, 1913.
Van Buren	Chas. M. Frey†	July 1, 1913.

*Resigned March 15, 1913
†Employed in the western part of the county during the school vacation

Considerable time has been given to helping select the men for county positions. It is also my duty to aid the men in starting their work, to visit them in their counties and give them whatever assistance I can. Two conferences of the men have been held at the college for the purpose of planning the work and for connecting it as closely as possible with the activities of the college.

The counties in which there are now agriculturists do not give an adequate idea of the demand for these men as there are twelve counties that have formed good organizations, held meetings in various parts of the county for explanation of the work and raised considerable funds for financing it. In addition to the counties now having agriculturists and those that have organized and raised funds, there are thirty-five that have applied for information as to methods of organizing and for assistance by a personal visit to the county to explain the work.

Upon assuming his work the county agriculturist is directed to make a preliminary survey of the county, studying it from every angle with a view to acquiring as thorough a knowledge as possible of its history, geography, climate, soils, crops, animals, animal products, types of farming and markets. From federal and state reports and all other available sources of information as well as from his own preliminary surveys, he makes an inventory of the agricultural conditions of the county as the starting point for his future activities.

The next problem of the county agriculturist is the methods of reaching the farmers; these may be divided into two classes: (1) the visit to the farmer on his own farm, and (2) the community or group method. The county is too large a unit for the county agriculturist to confine himself to the first method if he would reach many of the farmers and be of greatest service to the people. In most of the counties now having agriculturists there are more than three thousand farms and it would require from three to five years to visit carefully all of the farmers. By supplementing the method of personal visitation with the group or community method, it is possible for the county representative to come into fairly close touch with the problems of all of the farmers and to be of considerable service to all. For this purpose, a farm bureau is organized. It is composed of local organizations from all sections of the county. The representatives of the local organizations together with the officers of the county organization constitute the cabinet of the county agriculurist. With them he confers and upon them he must depend to a large extent for information and advice as to the needs of the different sections of the county and for assistance in arranging conferences with small groups of farmers on the farms, at the school house or other place of assembly. At such conferences there can be careful consideration of plans to be pursued, methods already in use or results achieved. The community or group method also includes the influence which the agriculturist may have through the schools, boys' and girls' clubs, churches, farmers' organizations, commercial associations, the county Y. M. C. A., the platform and the press.

In meeting the many problems arising in the agriculture of a county, the functions of the county agriculturist may be investigational, administrative or educational, but in all of these activities he has the assistance of others. He is the secretary of the agricultural interests

of the county. He co-operates with the College, the Experiment Station and the Government in all phases of their extension work and his constant and close relationship to the problems and needs of the farmers makes him an efficient intermediary between the agricultural activities of the county and these institutions. Out of his own training and experience, he may often safely advise but he also performs a very valuable service in bringing the problems of the farmer and of the rural community into closer relation to the work of the various specialists of the college. In addition to this he is the representative of the people in all their other agricultural activities.

The work which the county agriculturists are doing may be considered under four divisions: (1) soil problems; (2) specific farm enterprises; (3) the farm as a unit or as an organization of farm enterprises; (4) the community in its relation to the farm, the farmer, and successful agriculture. Under the first two divisions the extension methods have been fairly well tested and established. In the consideration of the second and third divisions of the work, extension must, for the most part, follow investigation. In the third division the focus of our attention will be not upon the yields of a particular crop or farm enterprise but upon the organization of the farm enterprises into a system, which under given conditions of production and distribution will give the largest net income for the farm as a whole. This involves not only an application of the physical and biological sciences to farm problems but also the science of economics. The fourth division of the work is a recognition of the fact that the success of modern farming depends very largely upon the nature of the community in which the farm is located. Today the most successful farm can not be established in an unorganized and indifferent community and sociological investigations will often need to precede the really valuable efforts to assist in the building of the more highly organized rural communities.

Respectfully submitted,

EBEN MUMFORD,

State Leader Farm Management

Field-Studies and Demonstrations.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEAN OF ENGINEERING.

Dr. J. L. Snyder, President Michigan Agricultural College:

My Dear President Snyder—I have the honor to present to you my sixth annual report as Dean of Engineering.

The *student enrollment* in the Division of Engineering for the year just closing is

Sub freshmen	40
Freshmen	143
Sophomores	106
Juniors	89
Seniors	53
Specials	3
Total	434

The total 434, in comparison with the totals of the last ten years is below that of any year since 1909-10. This showing would be a matter of concern if peculiar to the engineering course of this institution. The situation is very general, however, as indicated by the figures in Table I.

TABLE I.—ENROLLMENT IN ENGINEERING SINCE 1903 AT VARIOUS COLLEGES OFFERING ENGINEERING COURSES.

	Purdue University.*	Iowa State College.*	M. A. C.	Total of 55 Colleges.**
1903-4	1,067	503	353	10,600
1904-5	1,140	534	395	11,900
1905-6	1,234	570	393	13,400
1906-7	1,332	592	384	14,300
1907-8	1,402	701	485	15,500
1908-9	1,297	681	498	15,600
1909-10	1,207	602	500	15,500
1910-11	1,136	623	481	15,400
1911-12	1,105	587	453	14,900
1912-13	1,006	585	437	14,500

*See Iowa State College Engineer, Dec., 1912.
**See Bulletin, Society for the Promotion of Engineering Education, June, 1913.

A committee of the Society for the Promotion of Engineering Education (See Bulletin S. P. E. E. for June, 1913) assigns the following reasons for the decrease in attendance.

1. The general raising of standards both for entrance and for graduation.
2. The greater interest in courses in agriculture.
3. The greater interest in commerce courses.
4. The prevailing opinion that the engineering profession is overcrowded.

The same committee adds: "Undoubtedly the panic of 1907 had something to do with the attendance, probably causing the freshman class

of that year to be smaller, thus affecting the attendance materially in the following years" and

"The decrease in attendance at engineering schools should have a marked effect on the salaries paid to recent graduates. That this is true is indicated by the fact that a large majority of the schools who have any information on the subject report a material increase ranging from 10 to 50 per cent. A large number estimate that the increase is about 25 per cent."

In this matter of attendance, the outlook at M. A. C. is for increase. The present enrollment of freshmen engineers is 10 per cent greater than for the preceding year. Undoubtedly, the recent action of the University of Michigan in increasing materially its tuition fees to residents of the state will increase the enrollment in engineering at M. A. C.

The *teaching staff* of the division consists of 32 persons. The salaries paid are increasing slowly as appears from the comparison in Table II.

TABLE II.—COMPARISON OF SALARIES IN DIVISION OF ENGINEERING, 1907-8, 1909-10 AND 1912-13.

Composition of staff.

Period.	Professors.	Assistant Professors.	Instructors.	Assistants.	Total.
1907-8..........	3	4	....	....	....
1909-10..........	4	5	18	3	30
1912-13..........	4	7	17	3	32

Average salaries.

Period.	Professors.	Assistant Professors.	Instructors.	Assistants.	Total Expenditures.
1907-8..........	$2,433 00	$1,300 00	$812 00	....	....
1909-10..........	2,550 00	1,380 00	884 00	$720 00	$35,180 00
1912-13..........	2,675 00	1,571 00	1,014 00	730 00	41,150 00
Desirable*........	3,000 00	2,000 00	1,400 00	900 00	....

*See Report of Dean of Engineering for 1907-8.

The present scale of salaries, combined with the lack of opportunity for and encouragement in the prosecution of experimental and other investigation work does not assure the retention of many of our promising men and makes others discontented. In this connection, I wish again to recommend that the engineering experiment idea be made a realization.

This feature of engineering school work, once established would inure to the mutual benefit of the state, college, division, and engineering faculty and students.

The *professional degrees* were recently conferred on eighteen graduates of our engineering course. The conditions precedent to these degrees are such as give them real significance, much more than the same degrees conferred for work in course.

Our graduates are rapidly increasing in numbers and their standing makes it not at all difficult to find many who, at the suggestion, can qualify for these degrees.

The *course of study* as revised on the basis of twenty recitation hours per week or equivalent has been given a thorough trial and proven to be an improvement over the old course. I think that in a few years a still further reduction in credit hours should be made. The *general* character of the course which has been maintained for many years and which is peculiar to M. A. C. is in line with the latest opinions as to the work which should be given to undergraduates in engineering schools.

The recent *legislative enactment* limiting the annual budget of the division of engineering to $35,000, will, if given force and effect, be a body blow to the progress of the engineering work at M. A. C. Pending a decision as to the legality of the limitation nothing can here be said in way of recommendation for the future of the departments concerned. Suffice it to say that the budgets of the departments of the engineering division for the year past totaled $51,000 and that this amount does not include overhead charges.

It is sincerely to be hoped that the limitation can be removed. Otherwise the outlook for engineering at M. A. C. is very discouraging.

In conclusion I wish to commend the teaching staff and the student body in the division for their co-operation and loyalty during the year past and to thank the authorities and other departments for their support of the work in engineering.

Respectfully submitted,
G. W. BISSELL,
Dean of Engineering.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF MECHANICAL ENGINEERING.

Dr. J. L. Snyder, President Michigan Agricultural College:

My Dear President Snyder—This communication constitutes my sixth annual report as Professor of Mechanical Engineering.

The *teaching staff* of the department for the year past is as follows:

G. W. Bissell, Professor;

J. A. Polson and E. J. Kunze, Assistant Professors;

J. L. Morse, T. W. Fitzgerald, E. A. Evans, A. P. Kreutel, E. C. Baker, W. R. Holmes, A. S. Smith and J. Smith, Instructors.

In addition, Mr. C. D. Curtiss of the Civil Engineering department was transferred to my department for the winter term and some student assistants were employed during the same term.

The appended table, Exhibit A, shows the working schedule of the staff for the three terms of the college year.

No changes in the *personnel* are contemplated for the coming year. Mr. J. A. Polson has been advanced to the rank of associate professor with a seat in the general faculty and increase in salary. Messrs. Kunze, Morse, Fitzgerald and A. S. Smith have been given increases in salary.

Miss Clara B. Purcell, who has for nine years been connected with

the department as clerk, has chosen to sever her connection with the college, effective September 1, 1913, much to the regret, not only of the teaching staff and students in the department, but to all in the division of engineering who have known her.

It is unfortunate that the policy of the college in the matter of remuneration for clerical work makes it impossible to retain as efficient a person as Miss Purcell.

The *material equipment* of the department has been increased by the addition of a horizontal boring mill, an electric blue printing machine, a 75-ton hydraulic testing machine, a fatigue testing machine, a scleroscope, many small tools and apparatus, purchased or built in the shops and the entire equipment has been placed in good repair.

The *teaching efficiency* of the department is improving, due largely to the permanency of the staff and to the interest shown by each of the teachers in his work and that of others in the department, in the division and in the college.

The writer takes this opportunity to thank the teachers of the department and the students in their classes for the helpful and enthusiastic co-operation manifested during the year.

Respectfully submitted,
G. W. BISSELL,
Professor of Mechanical Engineering.

East Lansing, Mich., June 30, 1913.

EXHIBIT A.—TABLE I.

Class-work of Department of Mechanical Engineering, Fall Term, 1912.

Class.	Subject.	No. of course.	Teacher.	Hours per week each student.	No. of students enrolled.	Student hours per week.
4-year Freshmen	Wood shop	2 a	Mr. Krentel, Mr. A. Smith	6	135	810
Sophomores, Juniors	Forge shop	2 d	Mr. Holmes	6	54	324
Sophomores	Foundry	2 f	Mr. Baker	6	43	258
Sophomores	Empirical design	6 a	Mr. Morse, Student assts	6	103	618
Sophomores, Juniors	Machine shop	2 h	Mr. Evans, Mr. J. Smith	6	79	474
Juniors, Seniors	Machine shop	2 k	Mr. Evans, Mr. J. Smith	6	18	108
Juniors	Machine design	6 e	Prof. Kunze, Mr. Morse	3	49	147
Juniors	Metallurgy	11 a	Prof. Polson, Prof. Kunze, Mr. Morse, Mr. Fitzgerald	2	82	164
Seniors	Steam engine design	8 b	Prof. Kunze	6	25	150
Seniors	Engineering, Laboratory	13 c	Prof. Polson, Mr. Fitzgerald	8	51	408
Seniors	Heating and Ventilation	18 a	Prof. Bissell, Prof. Polson	3	28	84
Seniors	Costs, Accounting, etc.	18 c	Prof. Bissell	2	56	112
Totals					723	3,657

TABLE II.

Class-work of Department of Mechanical Engineering, Winter Term, 1913.

Class.	Subject.	No. of course.	Teacher.	Hours per week each student.	No. of students enrolled.	Student hours per week.
4-year Freshmen	Wood shop	2 b	Mr. Krentel Mr. A. Smith	6	122	732
4-year and 5-year Freshmen	Elements of Engineering	1	Prof. Bissell	2	128	256
Sophomores, Juniors	Forge shop	2 e	Mr. Holmes	6	47	282
Sophomores	Foundry	2 f	Mr. Baker	6	34	204
Sophomores	Kinematics	6 b	Prof. Kunze Mr. Curtiss Student assts.	5	98	490
Sophomores Juniors	Machine shop	2 i	Mr. Evans Mr. J. Smith	6	89	534
Juniors	Engines and boilers	7 a	Prof. Kunze Mr. Morse Mr. Fitzgerald	3	80	240
Juniors	Machine design	6 d	Mr. Morse	6	47	282
Junior	Engineering Laboratory	13 a	Prof. Polson Mr. Fitzgerald Mr. Curtiss	4	80	320
Seniors	Engineering Laboratory	13 d	Prof. Polson Mr. Fitzgerald	8	23	184
Seniors	Machine shop	2 l	Mr. Evans Mr. J. Smith	6	11	84
Seniors	Works Management	5 a	Prof. Kunze	3	46	138
Seniors	Jig and Fixture Design	6 e	Prof. Kunze	8	27	216
Seniors	Power Station Design	18 b	Prof. Bissell	7	25	175
Totals					860	4,137

TABLE III.

Class-work of Department of Mechanical Engineering, Spring Term, 1913.

Class.	Subject.	No. of course.	Teacher.	Hours per week each student.	No. of students enrolled.	Student hours per week.
4-year Freshmen	Wood shop	2 c	Mr. Krentel Mr. A. Smith	6	124	726
Sophomores	Forge shop	2 e	Mr. Holmes	6	33	198
Sophomores, Junior	Foundry	2 g	Mr. Baker	6	48	288
Sophomores Juniors	Machine shop	2 j	Mr. Evans Mr. J. Smith	6	69	414
Juniors	Thermodynamics	17 a	Prof. Bissell Prof. Polson Prof. Kunze	4	68	272
Juniors	Engineering Laboratory	13 b	Prof. Polson Mr. Fitzgerald	4	67	268
Juniors	Steam engine design	8 a	Mr. Morse	4	43	172
Seniors	Gas power engineering	8 c	Prof. Kunze	3	32	96
Senior	Machine tool design	6 f	Prof. Kunze	6	10	60
Seniors	History of engineering	18 d	Prof. Bissell	2	50	100
Senior	Thesis	19 a	Prof. Bissell Prof. Polson Prof. Kunze	20	16	320
Totals					557	2,914

REPORT OF THE DEPARTMENT OF CIVIL ENGINEERING.

President J. L. Snyder:

Dear Sir—While our departmental machinery has turned out good work during the past year, in some respects we have not attained results which are wholly satisfactory. The main reason for this unpleasant fact exists in an inadequate force provided to deal with the teaching which falls to our share, and the clerical tasks which arise partly from the teaching and which are partly assignments dependent upon the general college administration. Except in the winter term, our schedule was much over crowded and certain classes were assigned to men by way of makeshift rather than because the teachers were always qualified to take the work.

There has been no lack of industry on the part of our instructors. They have all responded to every demand with the best efforts they had to give. Every member of the teaching force is entitled to my thanks and those of the college for his efficient endeavor, loyalty, and the promotion of harmony in the department economy.

We began the year with a departmental staff including the following teachers whose names are given in order of seniority of appointment:

H. K. Vedder, C. E., Professor of Civil Engineering;
W. B. Wendt, B. C. E., Assistant Professor of Civil Engineering;
A. M. Ockerblad, B. S. in C. E., Instructor in Civil Engineering;
C. A. Melick, D. C. E., Assistant Professor of Civil Engineering;
E. D. Kingman, Ph. B., Instructor in Civil Engineering;
C. D. Curtiss, B. S., Instructor in Civil Engineering;
C. W. Parsons, B. S., Instructor in Civil Engineering;
E. L. Shepard, B. S. in C. E., Instructor in Civil Engineering.

Three of those named above have resigned and will leave us with the close of this school year. Mr. E. D. Kingman and Mr. A. M. Ockerblad will undertake employment elsewhere, and Mr. C. D. Curtiss intends to specialize in certain engineering studies at Columbia University.

A number of my recommendations of last year which received no consideration so far as I can judge are more urgent for the future. The suggestion that we be allowed an assistant to care for instruments and laboratory equipment is now mentioned for the third time. The failure to provide this need is costing heavily in deterioration of equipment. Similarly the lack of sufficient office help has its sequel in incomplete and imperfect records. At present there is more clerical work arising in the office of this department in one week than was accumulated in a year's business fifteen years ago. A very important item in this is the work entailed by attending to the candidates for advanced degrees. This year there were more than forty applicants dealt with of whom thirty received degrees at commencement after having satisfied the requirements demanded by college regulations.

As for many years past I present herewith a tabulation showing the work of teaching as carried out by this department during the year:

it will answer questions of assignments, enrollment, class-rooms occupied, size of classes and the like. Such a table has its limitations which should be borne in mind by anyone who consults its columns. It does not aim to set forth all lines of department endeavor. It deals only with classes and class work, in which a certain number of students are met by one or more instructors. There are many other definite assignments shared by our teaching staff which do not appear in the table. Further, Mr. C. D. Curtiss was loaned to the mechanical department during the winter term and his class work in that department does not appear in our tabulations.

Class-work of the Department of Civil Engineering for the College Year, 1912-1913.

Class.	Subject.	No. of course.	Teacher.	Classroom.	Hours of meeting.	No. hours per week.	No. students in class.
Summer sch'l 1912. (2 weeks) Sophomores	Forest Topog	C.E. 2b.	Prof. Wendt	Vanderbilt, Otsego Co., Mich.		56	11
Fall term.							
Sophomores	Surveying (class)	C.E. 1a.	Mr. Curtiss	111	5	2	21
Sophomores.	Surveying (class)	C.E. 1a.	Mr. Parsons	118	5	2	18
Sophomores.	Surveying (class)	C.E. 1a.	Mr. Parsons	118	7	2	21
Sophomores.	Surveying (class)	C.E. 1a.	Mr. Curtiss	120	7	2	21
Sophomores	Surveying (class)	C.E. 1a	Mr. Oekerblad	203	5	2	19
Sophomores.	Surveying (class)	C.E. 1a	Mr. Kingman	111	7	2	21
Sophomores.	Surveying (field)	C.E. 1a.	Mr. Parsons, Mr. Curtiss	401	1,2	2	50
Sophomores.	Surveying (field)	C.E. 1a	Mr. Curtiss, Mr. Oekerblad	203	5,6	2	52
Sophomores	Surveying (field)	C.E. 1a	Prof. Wendt	120	7,8	2	19
Juniors	Mechanics of Eng.	C.E. 4a	Mr. Shepard	301	5	5	20
Juniors	Mechanics of Eng.	C.E. 4a	Mr. Kingman	302	1	5	17
Juniors	Mechanics of Eng.	C.E. 4a	Mr. Oekerblad	301	1	5	20
Juniors	Mechanics of Eng.	C.E. 4a.	Prof. Melick	120	5	5	19
Juniors	Adv. Surveying (class)	C.E. 6.	Mr. Shepard	118	2	3	21
Juniors	Adv. Surveying (class)	C.E. 6.	Mr. Oekerblad	203	2	3	21
Juniors	Adv. Surveying (class)	C.E. 6.	Prof. Melick	302	7	3	19
Juniors	Adv. Surveying (class)	C.E. 6.	Mr. Curtiss	203	8	3	26
Juniors	Adv. Surveying (field)	C.E. 6.	Mr. Oekerblad, Mr. Shepard	203	6,7	4	22
Juniors	Adv. Surveying (field)	C.E. 6.	Mr. Shepard, Mr. Oekerblad	203	6,7	4	21
Juniors	Adv. Surveying (field)	C.E. 6.	Prof. Melick, Mr. Shepard	302	3,4	4	19
Juniors	Adv. Surveying (field)	C.E. 6.	Prof. Melick, Mr. Shepard	302	3,4	4	22
Jun. & Sen.	Surveying methods (class).	C.E. 2.	Prof. Wendt	203	1	3	17
Jun. & Sen.	Surveying methods (field)	C.E. 2.	Prof. Wendt, Mr. Curtiss	203	1,2	4	17
Seniors	Graphic Statics	C.E. 4d.	Prof. Melick	301	1	3	17
Seniors	Graphic Statics	C.E. 4d.	Prof. Melick	301	2	3	12
Seniors	Adv. Surveying (class)	C.E. 6b.	Prof. Vedder	111	1	5	13
Seniors	Adv. Surveying (class)	C.E. 6b.	Prof. Vedder	111	4	5	12
Seniors	Adv. Surveying (field)	C.E. 6b.	Prof. Vedder, Mr. Parsons	111	5,9	4	15
Seniors	Adv. Surveying (field)	C.E. 6b.	Prof. Vedder, Mr. Parsons	111	5,9	4	10
Seniors	Bridge Stresses	C.E. 8a	Prof. Vedder	111	2	3	13
Seniors	Bridge Stresses	C.E. 8a	Prof. Vedder	111	4	3	16
Seniors	Hydraulics	C.E. 5.	Mr. Kingman	111	3	5	27
Seniors	Hydraulics	C.E. 5	Prof. Wendt	203	4	5	24
Seniors	Hydraulic Laboratory	C.E. 5a	Mr. Kingman	3	5,9	4	7
Seniors	Hydraulic Laboratory	C.E. 5a	Prof. Wendt	3	5,9	4	9
Seniors	Hydraulic Laboratory	C.E. 5a	Prof. Wendt	3	5,9	4	10
Seniors	Hydraulic Laboratory	C.E. 5a	Mr. Kingman	3	5,9	4	7
Totals	37 sections					129	715

Class-work.—Continued.

Class.	Subject.	No of course.	Teacher.	Classroom.	Hours of meeting.	No. hours per week.	No. students in class.
Winter term.							
Juniors.....	Mechanics........	C.E. 4b.	Mr. Parsons...........	302	1	5	12
Juniors.....	Mechanics..........	C.E. 4b.	Mr. Ockerblad.........	203	1	5	13
Juniors.....	Mechanics.........	C.E. 4b.	Mr. Ockerblad..........	203	5	5	12
Juniors.....	Mechanics........	C.E. 4b.	Mr. Shepard...........	213	1	5	12
Juniors.....	Mechanics	C.E. 4b.	Mr. Shepard...........	302	5	5	11
Juniors.....	Mechanics	C.E. 4b.	Prof. Vedder............	111	5	5	12
Juniors.....	Advanced Surveying	C.E. 6..	Mr. Ockerblad........	213	2	3	9
Jun. & Sen..	Agr. Eng..............	C.E. 3 .	Prof. Vedder............	111	2	5	28
Seniors.....	Masonry, Arches (class).	C.E. 9..	Prof. Wendt................	109	1	3	12
Seniors.....	Mas'y, Arches (drawing).	C.E. 9..	Prof. Wendt, Prof. Melick ...	304	7,8	4	12
Seniors.....	Mas'y, Arches (drawing).	C.E. 9..	Prof. Melick, Prof. Wendt ..	306	3,4,7,8	4	17
Seniors.....	Masonry, Arches (class)	C.E. 9..	Prof. Melick...............	213	5	3	17
Seniors.....	Bridge Design....	C.E. 8b.	Prof. Melick, Mr. Parsons .	301	3,4	8	29
Seniors.....	Roads and Paving	C.E. 10.	Mr. Kingman..............	111	1	2	18
Seniors.....	Roads and Paving	C.E. 10.	Mr. Kingman...............	111	7	2	13
Seniors.....	Water Supply & Sewerage.	C.E. 15.	Prof. Wendt...............	203	2	4	18
Seniors.....	Water Supply & Sewerage.	C.E. 15.	Mr. Kingman	302	2	4	10
Seniors.....	Fxperimental Lab... ...	C.E. 12.	Mr. Ockerblad, Mr Shepard	4	2,3,4,6,7,8	6	10
Seniors.....	Experimental Lab.......	C.E. 12.	Mr. Kingman, Mr. Parsons, Mr. Shepard..............	4	6,7,8	6	16
Seniors.....	Mech. of Eng...........	C.E. 4a.	Mr. Kingman...............	111	8	4	14
Totals..	20 sections					88	295

Class-work.—Concluded.

Class.	Subject.	No. of course.	Teacher.	Classroom.	Hours of meeting.	No. hours per week.	No. students in class.
Spring term.							
Sophomores	Surveying (class)	C.E. 1b.	Mr. Curtiss	111	2	2	24
Sophomores	Surveying (class)	C.E. 1b.	Prof. Wendt	111	2	2	22
Sophomores	Surveying (field)	C.E. 1b.	Mr. Shepard, Mr. Parsons	304	3,4	4	24
Sophomores	Surveying (field)	C.E. 1b.	Mr. Shepard, Mr. Parsons	204	3,4	4	30
Sophomores	Surveying (field)	C.E. 1b.	Mr. Shepard, Mr. Oekerblad	304	6,7	4	20
Sophomores	Surveying (field)	C.E. 1b.	Mr. Shepard, Mr. Curtiss	204	5,6	4	23
Sophomores	Surveying (class)	C.E. 1b	Mr. Shepard	302	5	2	27
Sophomores	Surveying (class)	C.E. 1b.	Mr. Shepard	301	7	2	28
Sophomores	Surveying methods (class)	C.E. 2	Prof. Wendt	111	5	3	15
Sophomores	Surveying methods (field)	C.E. 2	Prof. Wendt, Mr. Curtiss	111	5,6	7	15
Juniors	Railroad surveying (class)	C.E. 7	Prof. Melick	111	1	3	28
Juniors	Railroad surveying (class)	C.E. 7	Prof. Melick	111	7	3	25
Juniors	Railroad surveying (field)	C.E. 7.	Prof. Melick, Mr. Kingman	111	1,5	4	25
Juniors	Railroad surveying (field)	C.E. 7	Prof. Melick, Mr. Kingman	302	5,8	4	14
Juniors	Railroad surveying (field)	C.E. 7	Prof. Melick, Mr. Kingman	302	5,8	4	14
Juniors	Topog. Mapping (field)	C.E. 6a.	Prof. Wendt, Mr. Curtiss	203	1,2	4	20
Juniors	Topog. Mapping (class)	C.E. 6a	Mr. Curtiss	203	2	2	20
Juniors	Topog. Mapping (field)	C.E. 6a	Prof. Wendt, Mr. Curtiss	111	7,8	4	22
Juniors	Topog. Mapping (class)	C.E. 6a	Prof. Wendt	203	8	2	22
Juniors	Mech. of Materials	C.E. 4c	Mr. Oekerblad	302	3	5	11
Juniors	Mech. of Materials	C.E. 4c	Prof. Wendt	203	3	5	13
Juniors	Mech. of Materials	C.E. 4c	Mr. Oekerblad	302	4	5	8
Juniors	Mech. of Materials	C.E. 4c	Mr. Oekerblad	203	6	5	12
Juniors	Mech. of Materials	C.E. 4c	Mr. Parsons	302	5	5	13
Juniors	Mech. of Materials	C.E. 4c	Mr. Parsons	302	6	5	10
Juniors	Mech. of Materials	C.E. 4c	Mr. Curtiss	203	4	5	8
Seniors	Roads (class)	C.E. 17	Mr. Kingman	120	4	2	22
Seniors	Roads (field)	C.E. 17	Mr. Kingman, Prof. Melick	120	3,4	6	22
Seniors	Astronomy (class)	C.E. 14	Prof. Vedder	111	1	2	28
Seniors	Astronomy (field)	C.E. 14	Prof. Vedder, Mr. Oekerblad, Mr. Parsons			2	28
Seniors	Contracts, etc	C.E. 13	Prof. Vedder	111	3	3	26
Seniors	Contracts, etc	C.E. 13	Prof. Vedder	111	4	3	23
Seniors	Thesis	C.E. 11	Prof. Vedder	111	5,9	20	28
Totals	33 sections					137	670

The following text-books have been used in our classes during the year: Merriman and Jacoby's Roofs and Bridges, Vols. I, II, III; Vedder's Notes on Surveying; Merriman's Treatise on Hydraulics; Church's Mechanics; Baker's Masonry Construction; Baker's Roads and Pavements; Turneaure & Russell's Public Water Supplies; Folwell's Sewerage; Hosmer's Astronomy; Tucker's Contracts in Engineering; Wilson's Topographic Surveying; Merriman's Mechanics of Materials; Allen's Railroad Curves and Earthwork; Breed and Hosmer's Surveying, Vol. I; Ingram's Geodetic Surveying; Harger and Bonney's Highway Engineers' Handbook.

The total expenditure by the department during the year for all purposes has been $2,693.12 of which $72.00 was turned in for special examinations, and $707.00 for laboratory fees and other departmental receipts.

Respectfully submitted,
H. K. VEDDER,
Professor of Civil Engineering.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF PHYSICS AND ELECTRICAL ENGINEERING.

President J. L. Snyder:

Dear Sir—During the year 1912-13, eighty-eight sophomore engineers took a year's work in physics. In the fall term, one hundred twenty-five sophomore agricultural students finished their second term's work in physics and in the spring of 1913, one hundred fourteen freshman agricultural students took their first term's work in physics. During the fall term fifty-six women completed their work in physics, and eighty-five freshman their first term this spring.

During this year the usual courses in physics, as above outlined have been maintained and in addition the second year short course men were given some "practical physics." The amount of work given to the agricultural students is too brief; although it is argued that the agricultural course is planned for those who go into practical agriculture, still the fact remains that quite a large per cent of the graduates take up teaching mainly to teach agriculture but it is necessary for them to teach other subjects as well, the result being that we have a good many agricultural graduates teaching physics in the high schools of the state who are not sufficiently trained to make good teachers of this subject.

If those who are to teach physics could elect one of the elective courses in physics it would help out very materially. This spring thirteen boys who had had our regular agricultural course in physics took an elective term and have profited considerably thereby. We offer a term's work in the fall on electrical subjects and also one in the spring on the use of power on the farm.

It is very convenient that the work in electricity and in physics are given by the same department as not only the students but many of the farmers are very anxious to get an acquaintance with electrical matters sufficient to enable them to use electricity intelligently on the farm. It is also increasingly important that the girls should have a practical knowledge of the application of the principles of physics to things with which they come in contact and to that end this fall we expect to put in the laboratory some of the more common appliances used in the home in order that these young ladies may become acquainted with their operation and maintenance. I think it would be desirable for the girls to put together and take apart a small pump which is commonly used about the house, vacuum cleaners and electric appliances generally; to be able to repair the wiring for flat-irons and electric heaters used about the house and to be able to renew fuses.

In the department of electrical engineering we have planned to separate the seniors in electrical and mechanical engineering in the fall term's work, giving the work to them in separate classes adapted to their needs.

I wish to acknowledge the hearty co-operation of the various members of the department during this last year. Mr. George Klotz, who

has been with us as caretaker since we came into the new Engineering Building has entered the employ of the city of East Lansing and it will be difficult to find someone to replace him.

Yours very truly,
A. R. SAWYER,
Professor of Physics and Electrical Engineering.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF DRAWING AND DESIGN.

President J. L. Snyder:

Dear Sir—I herewith beg leave to submit to you my annual report as head of the Department of Drawing and Design for the year ending June 30, 1913.

The full effect of the rearrangement of the schedule on a twenty credit basis was felt this year, showing how the work of teaching will be distributed throughout the three terms and among the different teachers in the department. It is not as even as might be desired, the fall term being quite light in teaching hours as compared with the other terms. I have made efforts to have this remedied but so far without avail. It will probably come in time with the growth of the college, and when, as I hope, the program may be made out by one or two responsible heads.

The courses in drawing, optional with music, continued to be very favorably received and the results, as shown in the work, proved even more satisfactory than they did the preceding year. I have to note a very marked enthusiasm in the freehand drawing courses, particularly this year. My efforts to offset the prevalent misconception that drawing is an art within the capacity of the few only, have certainly justified themselves this year as never before. If the teacher can make his students realize that individually they are all equally capable and able to acquire a valuable knowledge of a subject, his most difficult work is done, the rest lies with the student. This is where we succeeded this year almost beyond expectation. Enthusiasm ran to a high pitch and the results in some of the classes may be considered remarkable. Failure was unknown and not expected, and the weakest members of the class were able to turn out very acceptable, and here and there, very meritorious work,—as good as the best. At least two students decided to take up some form of drawing as a life work as a result of their year's work in the department.

Of course all of the above was made possible by the hearty and capable co-operation of all members of the department which I have in previous reports noted. I cannot say too much in praise of the faithful work of my staff, and as before I regret that financial remuneration is not available to make substantial the appreciation due the members.

I lose one of my faithful teachers this June, Miss Snelgrove who leaves to pursue further her studies in art at the University of Michigan. She became unusually capable and trustworthy being useful both in the freehand drawing and in the mechanical.

I am compelled to mention the sad fact that Miss Bartholomew, who assisted us in the winter term for a while, died suddenly at her home on March 7, in Lansing. She had been helping us from time to time in the teaching of our freehand drawing when the teaching hours became excessive for the department staff. Her work was always very satisfactory.

The department teaching has been done by the following staff mentioned in the order of seniority of appointment:

Victor T. Wilson,
Chace Newman,
Caroline L. Holt,
Isabel Snelgrove,
Walter H. Ward,
Carl Head,
Bessie Bartholomew, assistant in the winter term.
R. G. Chamberlin, student assistant in the winter term.
F. E. Andrews, student assistant in the winter term.

Nothing worthy of special note has been added to the department equipment during the year. We have quite a satisfactory outfit for the department provided the attendance does not increase markedly.

Heretofore I have appended tables showing the distribution of students and instructors, but I shall try the experiment of omitting it this time. Statistics are generally tiresome, and they run about the same from time to time.

Respectfully submitted,
VICTOR T. WILSON,
Professor of Drawing and Design.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEAN OF HOME ECONOMICS.

To the President, Dr. J. L. Snyder, Michigan Agricultural College:

Sir—I take pleasure in submitting my twelfth report as Dean of the Division of Home Economics. The work of the past year has progressed most satisfactorily. Notwithstanding the large enrollment, many applicants were turned away at the opening of the year for want of room.

Some advanced work and improved methods have been introduced into each of our four departments. Three teachers have been employed in music, one for part time only; three in domestic art, one carrying the woodwork only; Prof. Hunt and one other in domestic science, and one in physical training. More opportunity for actual teaching in domestic science and domestic art has been given our seniors and less for mere observation. The children from the East Lansing schools have formed two classes per week in both sewing and cookery and have been taught by the senior girls during the spring term.

Teachers and students alike have co-operated to make successful the extra occasions of the year, such as the Farmers' Institute Round-Up, the various banquets and dinners given by the college, the May Festival, the Bankers' Association, the Triennial Reunion, etc. Our house di-

rector has so skilfully managed the dining room that we have had as good board as at any time in the past, at the uniform rate of $2.10 per week throughout the year.

I wish also to call attention to the good work of our janitor and the door assistant, who have continued to meet the many requirements of their positions with efficient service.

That the class work of the women students has been satisfactory is shown by the low percentage of conditions received by them. It is possible that more constant scholarly work would be secured from all, were there less emphasis given to the social life.

We congratulate ourselves that six of our alumnae were given the promotion degree, Master of Home Economics, at the recent commencement. The theses presented show that housekeepers as well as teachers may carry on valuable investigations in home economics.

A brief resume of the development, the present conditions, and needs of the Home Economics division may be of value in shaping policies for the future.

The department had finished its first five years and the Women's Building had been occupied one year when I came to this position in 1901. The Building was not finished, nor was it all in use nor furnished. In my second year, however, it was practically all occupied. Furniture, pictures, statuary, equipment have been added and the Building and Terrace are both furnished for complete service. The gymnasium has been completed, its visitors' gallery built and new equipment installed; the shower bath rooms have been finished and lockers provided; the laundry and wood working rooms have both been fitted up; the domestic science laboratory has been completely refitted, as the equipment brought from the old laboratory was not longer adequate; and orders have gone in for new desks, sinks, cases and microscopes for the domestic art rooms. The day of small things for the Home Economics department is past and we are ready to enter on a larger, broader work.

During the fall term of the present year 72 girls (and several more stayed with friends in town waiting for vacancies) were taken care of in four private houses and in the Terrace. None of these places is well adapted for girls' rooms and the contrast with the lower expense and greater conveniences of the Women's Building makes these conditions all the more noticeable. Our dining room with normal capacity for 160 has been made to accommodate regularly over 200 people. For several years beginning in the fall of '03 when 26 were roomed out of the building, these off campus houses have been used with the hope that each year would be the last. The added responsibility, risk and labor involved cannot be appreciated except by the one in charge, the dean herself. No large girls' residence hall like ours should be without its elevator from basement to fourth floor; its convalescents' room, in order to isolate a patient for a day or over night; nor should it be without its guest room with opportunity to entertain an occasional college guest. Every available spot has been utilized, year after year, for students' rooms. Two have been put into space which sanitary science does not consider hygienic. This should no longer be allowed.

1. We need first a new residence hall, a larger dining room and an elevator in the Women's Building.

The duties of the dean's office have become so varied and considerable

that a regular stenographer should be employed to carry on the work. In addition to the correspondence, which is at times large, the dean issues all orders for supplies for class work, and furnishings and repairs for the building; she signs all bills belonging to the division and OK's the pay rolls for all regular and student employes. The women students are classified three times a year under her supervision; their records and blanks are filed in her office; she keeps lists of social activities and of those who attend; all excuses for absence from class and permits for absence from town are given by her; she acts as general adviser to the women students and for their organizations; her office is a bureau of information as far as may be, of the various matters pertaining to them. The four departments of work—music, physical culture, domestic art and domestic science—have grown in every way in these years, in numbers, courses, classes and character of the work.

During my first years the dean had two to five hours per week of teaching; for four years I met the seniors in the study of History of Education. Finding that other Michigan colleges had the right to issue state teachers' certificates I made inquiries and with the addition of one elective the catalogue of 1905-6 published a statement that this right had been granted to the Michigan Agricultural College. A teachers' registry was established in the dean's office, which was removed in 1908-09 to the office of Prof. French, the recently appointed professor of Agricultural Education. The Dean of Home Economics is naturally still called on every year to recommend teachers and to give her judgment on the merits of different candidates.

The attendance is now over 125% larger than it was when the present dean took up the work in 1901. The course of study has been advanced by one full year and more. The standard of work has been steadily increased. Hereafter none but high school graduates or the equivalent will be enrolled and all the work will be of college grade.

The dean is a member of a half dozen permanent committees and has her share of special committee work also. Various compilations of statistics, useful in showing the needs and possibilities of women's technical education might be made were there some one to make them.

II. A stenographer for the clerical work of the dean's office is the second important need.

Bulletins on home economics are being asked for constantly by the women of the state. Several topics have been accepted by different members of our staff but the time to finish and publish such papers is not available. Such bulletins would meet a long felt need.

Extension work is another field which has not been entered to any extent because of lack of time and of the demands of regular college classes. Had we another worker who could fit in as occasion demands at the college or as extension lecturer, some of the other instructors and professors would be free to prepare an occasional bulletin and to engage satisfactorily in extension work.

III. We need an additional instructor in home economics.

The salaries of our teachers are far below the average paid in institutions of this kind. If we expect to keep in the front ranks we must offer higher salaries. To illustrate: last year one of our instructors received here $700.00 and is receiving $1,200.00 now in a similar position at the University of Illinois. A letter is at hand asking for a teacher of

dressmaking in a state agricultural college of the middle west, who need not be a college graduate but who will be paid $1,000.00. Some of our graduates with little or no experience secure positions at $75.00 or $85.00 per month, while we try to retain experienced teachers at $700.00 per year. Other instances might be added.

IV. I most earnestly and respectfully plead for this important need of higher salaries for women teachers.

With adequate remuneration and sufficient helpers our department could carry on one-week courses throughout the state, a Home Makers' Week or short courses at the college in the winter, and perhaps a short summer course, using the splendid equipment on hand. The farm women and young girls who are not trained for a college course are asking for just such work. The State Grange and farmers' clubs, the Women's Congress of the farmers' institutes, the State Federation of Women's Clubs and other bodies are urging such work upon this division. In my reports of June, 1906, 1908 and 1909, I recommended a two-year course. The need still exists.

V. Bulletins, extension work, short courses are all imperatively needed and all are possible. It would be exceedingly unfortunate should this development be longer postponed.

VI. A two-year course ought to be inaugurated for those who have not completed the high school or who for some reason are not good candidates for a regular college course. M. A. C. is much better fitted for this work than any other institution in the state. Unless, however, she takes it up, some other will.

In 1903 the women of the college community organized a Women's Club and made the Dean of Home Economics its first president. The next year she was sent to the State Federation as delegate, where she was appointed member of the home economics committee. She has attended eight such conventions in various capacities, several board meetings, and was delegate to the National Biennial in Boston in 1908. She has been successively member and chairman of the Home Economics department, director of the State Federation, member and chairman of the education department, which last position she now holds. This work has brought me in touch with the women of the state and particularly with their educational interests. I have addressed on educational topics, several city and county federations and over forty clubs in various parts of the state during the past four years.

In a few cases the clubs have met my expenses, in a large proportion of these visits, however, my expenses have been paid by the college. I have taken one trip outside the state during my term of office when the expenses were met by the college, the occasion being the inauguration of Pres. Pendleton at Wellesley College.

The Girl Students' Aid Fund is under the auspices of the College Women's Club—two or three other clubs and individuals having contributed—and is administered by the Dean of Home Economics and Cashier of the College. Thus far, nearly $250.00 have been secured and most of it is in use to be returned later with a small amount of interest. This is a much needed work.

I have been a member of the State Committee of the Young Women's Christian Association since 1907 and actively interested in Association work at the college. This has become a most important feature of our

college life. I have attended during these years eight annual conventions, a National Quadrennial, a Students' Council and a Lake Geneva Conference of the Young Women's Christian Association.

In these twelve years I have visited all the colleges of Michigan, some of them more than once, and have endeavored to keep in touch with the college work of the state. I have also attended several sessions of the School Masters' Club and of the Michigan Academy of Science. It has been my good fortune to visit also during this time seventeen or eighteen other higher institutions of learning in this country and Canada, to inspect their equipment and learn something of their methods.

Two years ago by our invitation, women interested in home economics met here to organize the Michigan Branch of the American Home Economics Association. I was elected National Councilor for the Branch and have attended one annual convention of the National Association, the three state conventions held and several council meetings. I have attended also one of the Lake Placid Conferences on home economics at Lake Placid, New York. In order to prepare for the Graduate School in Home Economics which was held at M. A. C. in 1912, I visited the school at Ames, Iowa, in the summer of 1910. On account of the health and summer school duties of the chairman of the home economics committee, I served as acting chairman for our school.

A year ago we organized an honorary society for home economics students, the Omicron Nu, which has already met with favor in other institutions. Two additional Chapters have been organized and several requests for charters have been received. One at Purdue will probably be installed in the near future.

A social club, "The Idlers," to which all women connected with the college are eligible, was organized several years ago to promote social life among non-society members and to take care of general social functions; among these may be mentioned the Hallowe'en frolic, Thanksgiving evening, Faculty dinner parties, a "Ministers' evening," the May Festival supper. Three new literary societies have been established in these years. As this system is strongly fixed at M. A. C. and as it presents some excellent features, still another society ought to be established, or the existing plan should be modified. Certain features of the present plan are exceedingly harmful in the home life of the department. The "bid day" must be abolished and opportunity for society membership or attendance should be given to all who wish it. This would be ideal.

Within the year there was organized at the college in connection with the women graduates of some twenty-five colleges resident in this vicinity, the Lansing Branch of the Association of Collegiate Alumnae. I have represented the Branch since its organization at a Deans' Conference, a National Convention and a National Council of the Association.

These points are given to show how wide the field in which a dean of women must be interested. Her time ought to go not only to the regular duties at the college and the hundred and one unexpected matters which arise to perplex, but also to these outside interests, taking some part in social activities and furthering the interests of the department in every way possible.

As a result of the experience of these years I believe a more liberal

policy toward the women students would result to advantage on both sides. The dean should feel free to let the young women decide most matters for themselves in the conduct of their daily college life.

Our progress has been hampered by the frequent change of teachers and the low salaries paid, the restricted facilities for housing women students and by the great prominence given to social affairs. This department has, without doubt, a great future before it. Practical technical training for women will be given within a few years in every school and institution which admits women. Professors and instructors must be prepared for these positions and the agricultural colleges should be ready to supply them.

I wish to express to the president and faculty my sincere appreciation of their consideration and assistance in carrying on the work of the women's department. In leaving this work I take with me most pleasant memories and wish for the Michigan Agricultural College and all those connected with it the greatest success and happiness.

Respectfully submitted,
MAUDE GILCHRIST,
Dean of the Division of Home Economics.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEAN OF THE VETERINARY DIVISION.

President J. L. Snyder:

Dear Sir—The report for the Division of Veterinary Science is herewith submitted.

In my last annual report was mentioned the proposed rearrangement of the courses of study and likewise the progress toward a more complete organization of the division. Five departments proposed at that time have been nominally created. The courses of the division (excluding subjects given in other departments of the college) have been distributed as then suggested, and, after trying out one full collegiate year, the increased facilities offered in instruction work bespeak the success of the arrangement. Each department so created has been placed under the supervision of a veterinarian of the teaching staff, and though each individual is immediately responsible to the Dean of Veterinary Science he, none the less, has an interest at stake in his efforts to so equip and conduct the department assigned to him as to stimulate work of a high character; naturally this redounds to material advantage of the division as well as to the enrollment therein.

Of the department of pharmacology, Dr. J. S. McDaniel has the following to say: "This department, created at the close of last year constituting one of the sub-divisions of the veterinary science course, has, with the new arrangement, had a very successful year. Work greatly improved, adding class room hours and constitutes an eminently workable schedule. That even greater efficiency may be attained, it will be necessary to add to the present equipment of our laboratory, but even with efficient equipment, progress that should be evidenced must be hindered as a result of the sandwiched-in condition of the laboratory

work of pharmacy and microscopic anatomy at present given the students in the same room.

"I shall hope to add materially to our collection of crude drugs that the students may gain even yet better knowledge of their physical and chemical properties in the study of materia medica; to our specimens of toxic agents for essential observation, testing and analytical work in toxicology and detection of poisonous substances. With the anticipated increased facilities for handling sick animals that seem to be all important to better training of the student, the practical utility of Pharmacology 3a, 3b and 3c (therapeutics) will be considerably enhanced. The course comprises a complete review of all other phases of pharmacology and embraces the practical application of pharmaceutal materials or agents to the cure or prevention of the diseased conditions to which the animal body is susceptible.

"Besides studies immediately under the designation of pharmacology my duties include laboratory instruction in Zootechnics 1 (animal restraint), Veterinary Science to the agricultural division junior and senior students (2a, 2b and 2c) and work in connection with both the first and second year short courses in agriculture; the aim being in these latter courses to make the subject as practical as possible, adaptable to farm conditions and as free from technicality as the subject will warrant. Aside from work immediately connected with instruction at the college, I have filled several engagements in conjunction with the Department of Agricultural Education, offering talks or discussions on subjects of general and special interest to the several communities visited."

In the department of surgery, Dr. J. P. Hutton, veterinarian in charge, makes the following summary of the work of the past year: "We have treated in the clinic (both medical and surgical)* during the college year just closed a total of 357 cases including horses, cattle, sheep, dogs, swine, poultry and cats; an average of 71 cases per student (work open only to junior (4) and senior (1) classes) which is a remarkably good report considering the adverse conditions under which we are forced to work. Of this number over 80% were surgical cases, a fact due more especially because we are entirely unprovided with facilities for sheltering and caring for sick patients; moreover a number of very interesting cases were necessarily turned away on account of these conditions. The quality of the work we are attempting to instill into the mind of the student is of very high order, but, owing to a lack of building facilities, is wanting in effectiveness, and there is grave danger of public condemnation unless we are given state aid in the immediate future.

"The subjects included in this department under the designations Surgery 1, 2, 3, 4, 5, 6 and 7 constitute respectfully courses in general surgery, lameness and soundness, principles of horseshoeing, surgical clinic, special surgery, obstetrics and advanced surgery, the latter optional to seniors."

Dr. Frank W. Chamberlain has charge of classes in microscopic and macroscopic anatomy, i.e., gross anatomy, embryology and histology. "Under the new schedule of courses, the work in macroscopic anatomy is advanced to the winter term, freshman year, and all courses are ex-

*The two clinics have been combined during the past year.

tended over a greater period of time. The subjects in this department are otherwise taught as heretofore except that every effort has been made to so arrange and classify the work as to enable the poorer students to more efficiently handle the subject, and at the same time benefit the more skillful. During the past year the courses have been considerably handicapped through lack of proper room for our classes, but we are hoping for more laboratory facilities in the immediate future."

In the department of medicine, the following sub-divisions have been in operation during the past year, and are under my personal supervision: Medicine 3a, 3b, 3c, 4a, 4b and 4c, 1a and 1b including courses upon principals of diagnosis as well as simple and infective diseases of animals. Beginning with two terms in the sophomore year, the work continues uninterruptedly throughout the junior and senior years, aiming to expound the facilities through symptom reading for the interpretation of animal diseases and also including a discourse upon all known ailments of a medical (not surgical) nature. Furthermore in Veterinary Science 1 and Zootechnics 1, opportunity is afforded my meeting the freshmen students, thus becoming acquainted with them in their first term in Veterinary Science 1, and later meeting them in a course wherein is considered the breeds and care of dogs and cats, Zootechnics 1.

During the fall and spring terms of the junior year, as a part of the clinical work designated Medicine 2a, 2b and 2c, arrangements and equipment have been completed for laboratory diagnosis of such cases as may come to the clinic and which warrant more detailed study or investigation than that attained through observation of the symptoms manifested. In this course the student aided by chemical, physiologic and microscopic research is led into the more intricate details of symptom reading. This class work, together with the details incident to the administrative duties of the Veterinary Science division, several trips in connection with farmers, dairy and other institutes, an address before the Annual Roundup, etc., has amply occupied my time throughout the entire period.

While detailing the work of the departments created within the Veterinary Science division, I am not unmindful of the painstaking and efficient aid given so generously by the other departments of the college, but desire to mention more especially my appreciation of the services from the Departments of Bacteriology, Botany, Entomology and Zoology where new and special courses have been created and conscientiously awarded the student.

It is unnecessary for me to enlarge further at this time upon our dire need of greater facilities; these matters are uppermost in the minds of each instructor connected with the Veterinary Science division, as is evidenced by their remarks quoted herein and has already been referred to in my earlier communication to you under date of May last. Suffice it to say that this matter has caused us great concern and it is hoped will be speedily adjusted through added building facilities. That the needs of the division may be met in such a way as to render this college competent to compete with veterinary institutions of our neighboring states, a group of one and two-story buildings has suggested itself to us, a ground plan for which accompanies this report. The plan does not attempt to complete the details of the suggested structure

further than in that most urgently needed department of clinic and surgery which it is hoped will be speedily erected.

We have graduated our first student as Doctor of Veterinary Medicine and at this writing, so early after his leaving the institution, stepping from the ranks of student into the professional field he has chosen, it is gratifying to make public note of his success in securing a position of responsibility and one where he should render aid of no little worth toward the prevention of disease among mankind and domestic animals alike.

For the next year it is anticipated that the work will be carried on as outlined for the past year and we shall hope to add to what has already been accomplished along the lines of agricultural extension and agricultural education; to inaugurate as soon as practical a course to graduate veterinarians with a hope that this division of the college may attain a high degree of usefulness. Already along this line have we demonstrated in no uncertain manner our ability to serve a useful purpose to live stock owners, and by our daily correspondence we have freely given such aid as may be possible through such channels. Moreover, during the past year we have visited a number of farms throughout the state, thus aiding in the control of disease that has from time to time come to our attention.

Many applications for our veterinary catalogue have come from prospective students in veterinary medicine, and we believe we have been fairly successful in our work of the past year considering our hampered quarters and inefficient facilities. Indeed, sufficiently apparent have been these several factors to fully satisfy us that, if the State of Michigan (with its live stock valuation approximating $140,000,000) will but give us the financial and moral support as I believe the importance of our work warrants, and thus permit the erection of such buildings as are imperatively necessary, we will be able to make the Division of Veterinary Medicine at the Michigan Agricultural College equal to any veterinary college in America, and likewise may we be a means of elevating veterinary science in the State of Michigan to a professional standard equal to that in any state in the Union; and, furthermore, by so doing can this college render first aid in the suppression of the annual loss of millions of dollars now charged to animal disease among the live stock industry of the State of Michigan. This is a mission in our power to fulfill and an obligation we owe the people of the state.

Our student enrollment has been materially increased during the past year, and, including the recently graduated senior, was as follows: Senior 1, juniors 2, sophomores 12, freshmen 11, specials 2 and post graduate 1. Total 29.

Respectfully submitted,
RICHARD P. LYMAN,
Dean of Veterinary Division.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF BACTERIOLOGY.

Pres. J. L. Snyder:

Dear Sir—It is a pleasure to report not only a maintenance of the high ideals established in the teaching work of this department but also, in respect to efficiency, what we consider an increase.

I have taken up the work in lectures in general bacteriology very much in the admirable manner adopted by my predecessor but have in addition given the lectures in sanitary science to agricultural and forestry students and to the Short Course students as I had formerly done. In all this work I have had occasion to receive the cheerful assistance in emergencies of Miss Northrup, Mr. Brown and Dr. Hallman. It sometimes appears to be an excessive and unnecessary burden to triplicate this lecture work, as is now necessary, owing to the lack of capacity of our only lecture room. Even with three sections, we are compelled to fill the aisles with chairs. The value of our lecture work might be materially increased by the introduction of a projection apparatus. However, we could not consider installing such an apparatus in any of the rooms at our disposal. An auditorium seating from 250 to 300 is almost a necessity for our work.

Under the direction of Dr. van Suchtelen, with the able assistance of Miss Benham and the help of advanced students in the subject, the laboratory instruction has attracted a greatly increased number of students. This work is elective and it is observed that it is elected by the very best students from the junior and senior classes. The accommodations are now taxed to their utmost. With a class in Market Milk and a class in General Pathology and other subjects for the veterinary students, we will be greatly embarrassed by our lack of room.

Dr. Hallman has ably handled the subjects given especially to veterinary students and has been cheerfully assisted by Mr. Himmelberger. A deal of time has been spent in preparing permanent preparations for future classroom work. As this work grows, a special laboratory must be equipped for microscopical pathology with similar equipment to that required for histology and embryology. There must also be provided an autopsy room.

Mr. Brown has very successfully conducted the short courses in dairying given by this department and the bacteriological part of the course in Market Milk.

Miss Northrup has repeated in her characteristically efficient manner the work in Sanitary Science and Hygiene of Foods given to the women.

On numerous occasions, it has been a pleasure to have a hearty response from Mr. Robbins, Mr. Hano and Miss Rademacher when called upon for aid in preparing material for the class room.

There have been no serious outbreaks of disease amongst the students during the year, but one or more of the detention hospitals have been in use almost constantly throughout the school year. They are a great convenience and without doubt are a great factor in checking the spread of infectious disease through the student body as well as through the

surrounding community. The college hospital in charge of Miss Ketchum has continued to demonstrate its usefulness in caring for non-contagious affections.

It would seem the part of wisdom to begin to make plans whereby we may protect the Red Cedar river from pollution by the raw sewage from the college. A sewage purification plant at this institution would not only constitute a necessary health measure, at least in a broad sense, but would present many educational features of vast importance to a certain class of students.

This year leaves me under great obligations to all those in the department, each of whom has shown a hearty spirit of co-operation and a fine sense of loyalty to me personally and, of greater importance, to those fragments of science and to the ideals for which this laboratory stands.

To you also I am indebted for your constant support and valued advice which have made the past successful year possible.

Respectfully,
WARD GILTNER,
Acting Professor of Bacteriology.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF BOTANY.

President J. L. Snyder:

Dear Sir—I submit herewith the annual report for the Department of Botany for the year ending June 30th, 1913.

The botanical staff for this year has remained the same as in the preceding year. I regret to report, however, that the resignation of Mr. J. C. Th. Uphof who has been in charge of the Botanical Garden and Herbarium, has been submitted and accepted in consequence of his having been appointed to a position elsewhere at greatly increased salary.

From about the middle of February until the middle of June, Professor G. H. Coons, Research Assistant in Plant Pathology, was absent on leave of absence pursuing studies at the University of Michigan for the degree of Ph. D.

The number of students enrolled during the past year has been as follows: fall term 432, of whom 315 were taking Freshman Botany and the remainder Advanced Botany.

Winter term 460, of whom 47 were taking Advanced Botany, 122 Sophomore Botany and the remainder Freshman Botany. The loss of 23 in attendance as compared with the attendance of the corresponding term of the previous year is due to the fact that botany was required of women in the sophomore year as well as of men up to this year but has not been required of them in the year just closed.

In the spring term there was a total of 321, of whom 52 were taking Advanced Botany and the remainder Freshman Botany.

In addition to this, there were about 40 enrolled in the short course in Fruit Diseases and about 55 short course students were enrolled in the course on Weeds.

During the course of the year some minor changes have been made in the equipment such as building of more cases to accommodate apparatus and supplies, additional shelves for the seed collection, etc. During the course of the year there were prepared and sent out to various high schools as well as to some of the County Agents in connection with the office of Farm Management, forty-eight sets of seeds of Michigan weeds, each set containing seed of about ninety weeds and for comparison, seeds of about ten cultivated plants with which the weeds are likely to be confused. Similarly, Professor Coons prepared and sent out to a number of high schools throughout the state, sets illustrating fifty of the more important plant diseases. Both sets were sold at a price just sufficient to cover cost of material and hired labor, no charge being made for the time of the regular members of the botanical staff as this was considered as work that falls directly within the province of the Botanical department.

Mr. Uphof, in charge of the Herbarium, has entirely rearranged the Herbarium in accordance with the system of Engler and Prantl, a system of classification most in use throughout the world at the present time. He also segregated the Michigan plants from the others. The collection of plants made under the direction of the Biological Survey of the State Geological Survey in the summer of 1911, has been mounted and will be placed with the Michigan collection as soon as room is provided by the construction of additional herbarium cases which have been ordered. Mr. Uphof also mounted over one thousand specimens of plants collected by me in Florida, a large part of which I am donating outright to the college Herbarium, the remainder of which are being placed with the Herbarium as a loan so long as I shall continue to be connected with the institution. In addition to these, the standard sets and collections of fungi and algae for which the department is a regular subscriber, have been received so that the number of plants belonging to the Herbarium has been increased by probably nearly three thousand in the past year.

I wish to urge the importance of extension work in the Botanical department along several lines including the dissemination of information concerning weeds and other plants and more particularly, in order to disseminate information concerning plant diseases and their prevention. At present the Research Assistant in Plant Pathology, Professor Coons, is engaged on certain research work for which he received salary from the Adams Fund. It is impossible for him to take the time away from this Adams Fund research and devote it to these other important services such as dissemination of knowledge concerning plant diseases. Furthermore, it is often desirable to send a man to various points through the state to visit farms or orchards where certain diseases seem to be creating particular havoc. To send Professor Coons would mean to take him away from the work for which he is paid by the Government. It seems to me, therefore, that this work ought to be undertaken, as it is in so many other states, at state expense. The appointment of such a man would make it possible to bring the Botanical department in its activities into much closer touch with the people of the state.

Finally, I wish to commend the extreme loyalty of the teaching force of the department in spite of the fact that, especially in the winter

term, many of them were so overloaded with work that they were overworked almost to the breaking point. I feel it is only due to them that their courage and faithfulness be recognized and that another year, conditions should be changed so that it may not be necessary to overwork them quite so severely.

Respectfully submitted,
ERNST A. BESSEY,
Professor of Botany.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF CHEMISTRY.

President J. L. Snyder:

Dear Sir—In July, 1912, our first Graduate School furnished me with an opportunity to give some advanced instruction to a small class of young ladies in Domestic Science Chemistry. As near as possible in our work, which was entirely of a "laboratory and discussion" character, we took up work which assisted the students in understanding more clearly some of the lectures delivered during the course of the Graduate School by Dr. Sherman of Columbia and Professor Mendel of Yale on "Food and Nutrition." Nine young ladies registered in this course. Their names and institutions with which they were connected being as follows:

Myrtle B. Craig, Lincoln Institute, Jefferson City, Mo.
Grace J. Ferguson, Kansas City, Mo. (High School).
Abigail M. Hess, Montana State College, Bozeman, Mont.
Mabel C. Mosher, Michigan Agricultural College, East Lansing.
Lena M. Pope, Manistee High School, Manistee, Mich.
Anna Rutherford, Traverse City, Michigan. (State Hospital).
Elizabeth S. Slaght (Mrs.), Grand Rapids High School, Grand Rapids, Michigan.
Anna Elizabeth Smith, State Normal School, St. Cloud, Minn.
Frances E. Stewart, Chicago, Illinois. (Wendell Phillips High School).

The work with the freshmen students in the fall term in Chemistry (1) was carried out in a manner similar to that pursued in previous years, but I desire to call your attention to the following compilation:

Of the total number of students registered in the class in the various courses 55.25% had previously studied chemistry in a high school.

Of the total number who took the final examination 95.7% passed the subject, 4.3% failing.

During the term. of the total number who registered 3.9% withdrew.

Of the failures previous referred to 20% were students who had studied chemistry in a high school.

I feel that so far as possible during the coming year it will be best for us to differentiate the student who has studied chemistry in a good high school in his laboratory work with us from one who has had no chemistry, and therefore will ask for an additional assistant in the laboratory to carry out this idea.

The schedule of class work carried on throughout the year is as follows:

Fall Term, 1912.

Chemistry (1)—freshmen.		
Women	122	
Agriculturals	214	
Engineers	149	
		485
Chemistry (7), Quantitative Analysis, juniors		50
Chemistry (10), Organic Chemistry, women		83
Total taking work in Chemistry this term		618

Winter Term, 1913.

Chemistry 2, Qualitative Analysis, freshmen (men)	202
Chemistry 4, Agricultural Chemistry, juniors & seniors	44
Chemistry 6, Forestry Chemistry, juniors & seniors	12
Chemistry 9, Qualitative Analysis, women, freshmen	117
Chemistry 12, Mineralogy, freshmen	134
Chemistry 14, Senior Engineers	7
Total taking work in Chemistry this term	516

Spring Term, 1913.

Chemistry 3, Organic Chemistry, freshmen, (men)	182
Chemistry 16, Animal Nutrition, seniors	10
Chemistry 11, Domestic Science, senior women (flour)	3
Chemistry 13, Engineering Chemistry, freshmen	134
Thesis work in Forestry	6
Thesis work in Engineering	5
Total taking work in Chemistry this term	340

Early in the year 1913 the Board authorized the establishment of a laboratory for the study and testing of wheat flour. Under Asst. Prof. Clark, who has general direction of the work, the laboratory has gradually taken form and we now have a dough mixer, electrically driven; sponge closet, electrically heated and controlled; baking oven for baking the completed loaf, electrically heated; and an electrically heated muffle for use in determining the ash of wheat flours. The laboratory has proved its usefulness already and is attracting the attention of our senior students in Household Economics,—several of whom have taken the first term's work offered in this course. The idea at present is two fold; to impart a thorough knowledge of flour and its manufacture to our domestic science students and also to train a number of young ladies who desire to fit themselves for special work as flour testers in connection with some of the larger mills. The work in this flour laboratory taken in connection with the opportunity offered by the milling plant located in the Soils and Crops department permits of our students taking any sample of wheat, milling it to flour, determining the percentage of patent—low grade and offal—in the milling process and then later to take the highest grade product,—the patent, and determine

by the baking test how it compares with some of the standard grades of flour from the large milling companies of the West.

We have during the year added to our apparatus a fine rotation polariscope and also a double quartz wedge compensating saccharimeter,—both these instruments coming from the celebrated makers, Schmidt & Haensch of Berlin. We still have in our possession the original polariscope used by Dr. R. C. Kedzie to establish the fact that sugar beets could be grown in Michigan of sufficient richness to warrant the establishment of beet sugar factories. While the instrument is useful for coarser determinations its main value lies in its historic interest.

During the spring term five senior engineering students, who had elected a thesis involving chemical investigation, took special work under Asst. Prof. Huston.

Also six senior forestry students took thesis work of a chemical character under Asst. Prof. Clark.

On Jan. 22, 1913, I presented a paper before the State Millers' Association on "Something about Bran." On Feb. 21st I gave a talk before the Pedagogical Club at the Mt. Pleasant Normal on "The Mission of the Teacher." On April 24th I presented a paper before the Chemical and Physical Section of the Schoolmasters' Club at Ann Arbor on "The Relation of a Science Teacher to the Instruction of Agriculture in a High School," and as a reward for this effort was elected Chairman of this section for the year 1914.

I cannot let the opportunity escape to recommend strongly to you that some form of a summer school be established at this college. While the action which the faculty took during the past year was in a certain sense progress in the direction of establishing such a school, the effort came too late to make such a school available for 1913, but I feel that it will be of great advantage to the students of the college including the teaching force as well to have a short summer school given annually at M. A. C.

In closing I wish to acknowledge the faithful work done by my staff during the past year:

A. J. Clark, Assistant Professor.
R. C. Huston, Assistant Professor.
B. E. Hartsuch, Instructor.
F. W. Bentzen, Instructor.
J. R. Mitchell, Instructor.
G. A. Reddick, Instructor.
E. H. Conroy, Instructor.
F. C. Kaden, Student Assistant.
Mabel Mosher, Assistant.
E. A. Goodhue, Clerk.
G. W. Churchill, Caretaker.

Respectfully,
FRANK S. KEDZIE,
Professor of Chemistry.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF ENGLISH AND MODERN LANGUAGES.

President Jonathan L. Snyder:

Dear Sir—I have the honor to submit for your consideration and that of the Board of Agriculture the following brief report on the work of the Department of English and Modern Languages for the year ending June 30, 1913:

The Enrollment.—The student enrollments in the department this year numbered 2718, an average of 906 per term, distributed as follows:

	English.	German.	French.	Total.
Fall	733	73	71	877
Winter	835	63	57	955
Spring	777	62	47	886
Total for year	2345	198	175	2718

The Teaching Force.—The teaching force of the department consisted of 12, classified as follows:

By rank: 1 professor, 1 assistant professor, 10 instructors.

By sex: 9 men, 3 women.

By length of service at M. A. C.: 4 not previously employed, 8 previously employed.

The Work.—Outside of administrative work and many miscellaneous duties difficult to classify or explain, the labors of the members of the department were chiefly of the following six kinds:

First: Instructing in class the average of 906 students per term listed above.

Second: Preparing new material for class work and adapting existing material to the peculiar needs of students of this institution. (Existing text books contain matter only fairly well adapted for use with engineering students, and there is no text book in existence adapted to the composition work of agricultural students.)

Third: Reading and critically correcting many thousand themes written by students.

Fourth: Holding several hundreds of individual conferences with students concerning their themes and their work in public speaking, the purpose being to give the special advice, help, encouragement or reproof needed by individual students.

Fifth: Directing and training debating teams, contestants for oratorical honors, students taking part in plays, etc.

Sixth: Preparing committee work for, and taking part in, departmental meetings. (The main purpose of these meetings is explained below.)

The Course of Study.—It gives me much pleasure to say that the year's experience has convinced me that on the whole the course of

study in effect when I took up my work here in September was wisely planned and well adapted to the needs of our students. The changes which will be put into effect next year, while important, are not radical. It is my belief that the proper time to consider improvements in a given subject or in an entire course of study is when the successes and failures of that subject or of that course of study are vividly present in the mind. That time is the end of each term rather than at its beginning, and the closing weeks of the college year rather than September. Accordingly, groups of instructors teaching sections of the same class were called together near the close of the fall and the winter term, and a series of departmental meetings was held in May and June. In these meetings the course for next year was planned, the text-books chosen and the general methods of teaching agreed upon. These changes were discussed and understood by all, and were made matters of record. Consequently, not only has the course been carefully considered with the year's experience in mind, but each instructor knows what to expect and for what to prepare. I believe that this will do much toward giving to the department stability and certainty and that the work will be very materially improved.

The Debates.—This year, as last, the department supervised two inter-collegiate debates, one with Alma College, the other with the State Normal College at Ypsilanti. In our debate against Alma College the students representing us were Messrs. Robert Snyder, '14, Samuel Rabinowitz, '16, and N. E. March, '16. They showed excellent ability and careful preparation, received the unanimous decision of the judges and clearly deserved it. In the debate with the State Normal College we were represented by Messrs. Ernest Hart, '14, S. A. Jessop, '16, and G. T. Hayes, '15. It was a good debate, resulting in a victory for Ypsilanti by a two-to-one vote.

The Oratorical Contests.—The regular oratorical contest was won by Mr. A. I. Margolis, who accordingly represented this college in the state contest. Mr. Margolis won also our local peace contest, thus becoming our representative in the State Peace Oratorical Contest held at Ypsilanti. In this he won third place. It is worth recording that two of the five judges gave him first place and that the man who won over him was also successful in the inter-state contest.

A Tri-State Debate Next Year.—I am very glad indeed to report that preliminary arrangements have been made for a tri-state debate next year with the Iowa State College and the University of Minnesota. While in the past the success of our debating teams has been fairly good, the great majority of our most promising speakers have failed to work for places on the teams, and the general student interest in these intellectual contests has been very small. Other land-grant colleges, the most progressive in the United States, have developed debating to a high degree of excellence. They are using it to interest students in studying carefully important questions of the day and to train them in vigorous, practical power to write and to speak. Such men are needed not only in our general national life, but to carry forward the very principles for which the land-grant colleges stand.

Perhaps I should explain the tri-state system of debating: Each of the three colleges represented will choose two teams, one on the negative and one on the affirmative side of the question. Although arrangements

have not been completed, I can illustrate the method as follows: Each of the affirmative teams will debate away from home, while the negative teams debate at home. M. A. C. will send its affirmative team to Minnesota, Minnesota will send its affirmative team to Iowa, and Iowa will send to Michigan. Each college will thus hold two debates on the same evening, supporting the affirmative at home and the negative away from home, and the series will be won by the college receiving the greatest number of votes of the judges of the three debates. The number and character of the schools represented, the fact that some of the students will get an interesting trip to a great institution of a neighboring state, the fact that at the same hour when our men are contesting against Iowa on our local platform another of our teams is meeting a Minnesota team in St. Paul, while at Iowa State College Minnesota and Iowa fight for victory on the same question—all of these considerations should help materially to arouse our students to the fact that debating is not a mere departmental matter, but an important activity of the college as a whole. Already many students who showed no interest in this year's debates have said that they will work to win a place on one of our tri-state teams.

One circumstance hostile to debating will be removed when the college has an auditorium in which contests of the kind may be held. Some other adverse conditions peculiar to our college can be removed in time, and others perhaps cannot, but it is our hope that debating here may be brought to a standard of excellence which will compare with that of other institutions. The hearty sympathy and support of the President of the College, the Secretary of the Board and the heads of several departments, as shown when the tri-state debate was under consideration, will work strongly toward that end.

The Spirit of the Department.—The members of my department have shown throughout the year a most praiseworthy spirit. Their interest in preparing themselves to carry out the plans of next year is shown by the fact that five of them are now in summer school—one in the University of Chicago, and four in the University of Michigan. One has gone to Europe for the summer. Other members of the department are spending their time in ways of which I thoroughly approve. At the date of this report, no instructors have resigned. The increases of salary granted, while not large, have tended strongly toward creating a feeling that a policy of recognizing and rewarding faithfulness and efficiency has been begun. If such a policy has been adopted by the administration, then a teaching force of training and experience, of growing loyalty and increasing efficiency, can be held together. As it is necessary that nearly all teachers of English be drawn from institutions whose ideals are much different from those of a land-grant college, changes in the staff of the English department are of serious consequence. When new teachers are employed, they must be assimilated to the purpose, the method and the ideals of this institution. This takes thought and energy and time. To lose a teacher of English who has grown into real efficiency in a college of this kind is more serious than to lose such a teacher in any other kind of college. It is my earnest purpose to make this department stand for something definitely worth while, and I am sincerely grateful to you for the increases in salary

and for the other support which seem to indicate a purpose of standing behind the department and enabling it to carry out its plans.

Relation to Other Departments of the Institution.—I am glad to report that the other departments of the college have manifested a spirit of co-operation for which the Department of English is very grateful and which is essential to its success. In a large and a very true sense it can be said that composition is not a separate subject, to be separately taught. Composition is but the expression (both oral and written) of the student's thought on all subjects. A recitation in chemistry, a paper in botany, a report in farm crops—all of these are exercises in composition. Certain fundamental ideas and many details can be given by the English department, but in spite of the thousands of themes read by that department, by far the greater part of the student's work in composition is actually done in other departments. Unless the student be held to accountability on his oral and written composition in these departments, the poorly prepared student, the student of moderate ability and the indifferent student will make but little real improvement. The agricultural freshman spends two hours per week with his English teacher. Two hours per week is about one-fiftieth of his waking time. If the time spent in preparation equal that spent in the class room he may be said to spend one-twenty-fifth of his time on English. Now if the indifferent student be held to account for his manner of expression only when he is working for his English teacher, there is little hope for him. His manner of expression during twenty-four twenty-fifths of his time will overcome that of the remaining twenty-fifth. That is one reason why it must be recognized that the student should be required to cultivate good methods of expression, both oral and written, in every class.

Furthermore, it must be remembered that, with some exceptions, all composition work for men is limited here to the freshman year. It falls to other departments, then, not only to build upon, but even to preserve what the English department has done. If he is held to no accountability for his English, a student may write much worse as a senior than he did as a freshman. If it is not to affect his grades or even his reputation, why should he trouble himself to put in practice what he has learned? In referring to this matter I am entirely sincere in saying that the other departments have manifested some disposition to recognize these facts and to act upon them. For this all members of the Department of English are devoutly thankful.

I wish to say also that my predecessor has shown a generous interest in the success of the department this year. I found the records in admirable condition, and Dr. Blaisdell spent some time in going over with me various features of the work. He has also throughout the year shown a very friendly spirit of helpfulness, which I sincerely appreciate.

Very respectfully submitted,

W. W. JOHNSTON,

Professor of English and Modern Languages.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF ENTOMOLOGY.

President J. L. Snyder:

Dear Sir—Following is a brief report of the work of the department for the year ending June 30, 1913.

Eight regular courses in entomology have been given during the year, Course V being given throughout the entire year. Besides this, two short courses were given to short course students during the winter term. Course VI was given in its entirety for the first time, the laboratory work having heretofore been omitted to make room for other departments following the recent changes in course. Course VIII, Parasitology was given for the first time to seniors in the veterinary course.

The work of the department requires little comment. The work has been done with few breaks, and carried out as planned.

The personnel of the department has not changed except for the department of student assistants and the coming of new ones.

The legislature recently closed has placed the inspection of bees in the hands of the State Board of Agriculture, and they in turn have appointed Mr. F. C. Millen, a graduate of Ontario Agricultural College, as State Inspector, making him a member of this department and instructor of apiculture, his duties here to begin on September 1st. It is to be hoped that eventually courses in bee-keeping may be added to the curriculum.

Meetings of various sorts have claimed the services of the department in various parts of the state. Addresses have been made on a number of occasions to gatherings of farmers and state societies.

It gives me great pleasure to report a year pleasantly spent.

Respectfully submitted,

R. H. PETTIT,

Professor of Entomology.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF HISTORY AND ECONOMICS.

To the President:

The following is the report of the Department of History and Economics for the year 1912-1913.

Total number of enrollments in the department for the year equalled 900, distributed as follows:

By terms: Fall, 258; winter, 368; spring, 274.

By classes: Freshman, 106; sophomore, 401; junior, 239; senior, 125; specials, 26.

By subjects: History, 182; economics, 574; political science, 144.

Total number of hours taught during the year by members of the department were 1639, divided among the three terms as follows:

Fall term, 516; winter, 576; spring, 517.

By subjects, the number of recitation hours during the year equalled: economics, 1637; history, 345; political science, 382.

The studies which are included within the scope of this department are in the main studies of a very mobile character, and while the methods of research and investigation remain essentially the same from year to year, the subject matter of political science, economics and sociology is constantly changing. Ten years ago, for example, the trusts in economics and national expansion in political science, were the questions which were uppermost in the public mind, and the ones upon which emphasis was laid in teaching; now, they command scant attention in the classroom.

This variableness in the subject matter of the studies just mentioned shapes in no small degree the methods which are employed in teaching them. Professor Ryder, for instance, during the past year, finding that the control of public utilities, the initiative and referendum, and the problems of the suffrage were the political questions uppermost in discussion everywhere, utilized a term's work in the study of these problems.

This as it happened was the single term during which students had an opportunity to elect political science, but it was reasoned that students would derive more benefit from the intensive study of a few topics and these timely ones than they would from covering the whole subject of political science in the conventional way. Mr. Ryder also found that the subject was given concreteness and the appearance of reality,—in this way resembling laboratory study,—through bringing in legislators and public men to discuss special subjects before his students and special lectures were as a result largely used.

The natural variableness in the subject matter of these studies appeared also in the case of economics. The principles of this subject are found to be applicable to some of the phases of agriculture and the name agricultural economics has been given to the special application. At nearly all the places where agriculture touches human interests, an economic significance may be found but it is especially in relation to farm organization that economics is most helpful.

During the fall term of the past year a course in agricultural economics for advanced students was given, extending throughout two hours per week during the term. Three-fourths of this time was given to the study of farm organization and topics such as follows were discussed: "Factors in Farm Organizations," "Proportioning of the Different Factors to each other," "Size of Farms," "Farm Tenure," "Distribution of Farm Enterprises," "Systems of Agriculture," "Rotations," "Choice of Crops," etc.

It was found in connection with these topics that excellent problems drawn from study which the students had already pursued in other departments were obtainable and these added reality and gave zest to the lectures of the course. Indeed, from a pedigogical standpoint, agricultural economics offers admirable material in a college like this and it is quite possible also that the discipline of looking at the farm as a unified activity—the business point of view—may be the best result which shall come from the study of agricultural economics. The course will be given three hours per week instead of two, during the ensuing year.

The relation of the social sciences to agriculture were still further emphasized during this year through the presentation of a course in Rural Sociology. This subject was given throughout a period of sixty recitations to seniors and juniors and embraced the study of such topics as "Types of Rural Communities," "Drift of Rural Populations," "Advantages and Disadvantages of Farm Life," "the Rural Church," "Rural Schools," and "Rural Social Life." The study of these familiar topics of discussion and the attempts to suggest remedies for diseased conditions seemed to prove very interesting to the members of the class and the course will be repeated again next year.

Among the general college responsibilities of the head of the department, none have taken more time than the work of preparing for the triennial reunion of the alumni of this institution. Throughout the spring, a local alumni organization with which the head of the department, as alumni secretary, co-operated, had charge of preparing an alumni day program, a banquet, a ball, a band concert and a dramatic entertainment, together with issuing invitations and advertising alumni day events to our graduates and friends. It seems probable now that a permanent alumni secretary will soon be arranged for, after which the duties of the nature described above, will no longer be felt in this department. The duties connected with the secretaryship of the faculty, which, as described in our last report, were being carried by Professor Ryder, have devolved upon him permanently and occupy no small portion of his time and energy.

The personnel of the department remains unchanged and much credit is due to Professor Ryder and Instructors Hendrick and Dunford for the effectiveness of the work during the past year.

Very sincerely,
WILBUR O. HEDRICK,
Professor of History and Economics.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF MATHEMATICS.

President J. L. Snyder:

Dear Sir—I have the honor of submitting herewith the annual report of the Department of Mathematics.

The following is the list of the members of the department in order of seniority of appointment.

Warren Babcock, B. S., Professor of Mathematics.
M. F. Johnson, B. S., C. E., Instructor.
S. E. Crowe, B. A., Instructor.
*J. E. Robertson, B. S., Instructor.
E. E. Beighle, B. S., Instructor.
L. C. Emmons, B. S., A. B., Instructor.
H. A. Snepp, B. A., LL. B., Instructor.
R. H. Reece, B. S., Instructor.
G. G. Speeker, A. B., Instructor.
W. M. Wible, A. B., A. M., Instructor.
M. G. Fenerhak, B. A., Instructor.

Professor Warren Babcock was called by death on June 3rd, 1913. He was a member of the faculty of the Michigan Agricultural College for 22 years. When the Department of Mathematics and Civil Engineering was divided, in September, 1909, Professor Babcock was placed at the head of the Department of Mathematics, which position he held until his death.

Mr. James E. Robertson resigned on February 15th of this year, to accept a professorship at Hiland Park College, Des Moines, Iowa.

Mr. M. G. Fenerhak was secured for the remainder of the year to fill the above mentioned vacancy.

All the members of the department have signed contracts for another year, excepting Mr. Fenerhak.

The following is a schedule of the classroom work of the department arranged by terms:

Fall Term Schedule.

Class.	Subject.	No. of course.	Teacher.	Classroom.	Hour of meeting.	No. of hrs. per week.	No. of students in class.
Sub-fresh	Geometry	Math. 2a	Mr. Emmons	8 College Hall	9:50-10:45	5	23
Sub-fresh	Geometry	Math. 2a	Mr. Emmons	100 Ag. Hall	2:30- 3:25	5	19
Sub-fresh	Geometry	Math. 2a	Mr. Beighle	101 Ag. Hall	2:30- 3:25	5	19
Sub-fresh	Geometry	Math. 2a	Mr. Beighle	102 Ag. Hall	1:35- 2:30	5	13
Sub-fresh	Geometry	Math. 2a	Mr. Wible	101 Ag. Hall	12:40- 1:35	5	14
Sub-fresh	Eng. Alg	Math. 1e	Mr. Beighle	100 Ag. Hall	8:55- 9:50	5	17
Sub-fresh	Eng. Alg	Math. 1e	Mr. Robertson	103 Ag. Hall	1:35- 2:30	5	20
Sub-fresh	Ag. and W. Alg	Math. 1	Mr. Speeker	102 Ag. Hall	10:45-11:40	5	14
Sub-fresh	Ag. and W. Alg	Math. 1	Mr. Wible	101 Ag. Hall	8:55- 9:50	5	12
Sub-fresh	Ag. and W. Alg	Math. 1	Mr. Wible	101 Ag. Hall	10:45-11:40	5	13
Sub-fresh	Ag. and W. Alg	Math. 1	Mr. Crowe	2 College Hall	8:55- 9:50	5	13
Sub-fresh	Ag. and W. Alg	Math. 1	Mr. Snepp	103 Ag. Hall	2:30- 3:25	5	15
Sub-fresh	Geometry	Math. 2a	Mr. Crowe	103 Ag. Hall	10:45-11:40	5	16
Sub-fresh	Geometry	Math. 2a	Mr. Robertson	103 Ag. Hall	12:40- 1:35	5	17
Freshmen	Ag. and W. Alg	Math. 1b	Mr. Snepp	2 College Hall	8:00- 8:55	5	22
Freshmen	Ag. and W. Alg	Math. 1b	Mr. Snepp	102 Ag. Hall	9:50-10:45	5	16
Freshmen	Ag. and W. Alg	Math. 1b	Mr. Snepp	103 Ag. Hall	3:25- 4:20	5	23
Freshmen	Ag. and W. Alg	Math. 1b	Mr. Robertson	8 College Hall	8:00- 8:55	5	22
Freshmen	Ag. and W. Alg	Math. 1b	Mr. Robertson	103 Ag. Hall	9:50-10:45	5	21
Freshmen	Ag. and W. Alg	Math. 1b	Mr. Reece	101 Ag. Hall	8:00- 8:55	5	18
Freshmen	Ag. and W. Alg	Math. 1b	Mr. Reece	100 Ag. Hall	9:50-10:45	5	21
Freshmen	Ag. and W. Alg	Math. 1b	Mr. Reece	100 Ag. Hall	1:35- 2:30	5	19
Freshmen	Ag. and W. Alg	Math. 1b	Mr. Reece	100 Ag. Hall	3:25- 4:20	5	16
Freshmen	Ag. and W. Alg	Math. 1b	Mr. Crowe	8 College Hall	2:30- 3:25	5	23
Freshmen	Ag. and W. Alg	Math. 1b	Mr. Johnson	2 College Hall	9:50-10:45	5	16
Freshmen	Ag. and W. Alg	Math. 1b	Mr. Johnson	2 College Hall	2:30- 3:25	5	23
Freshmen	Ag. and W. Alg	Math. 1b	Mr. Speeker	301 Eng. Hall	9:50-10:45	5	16
Freshmen	Ag. and W. Alg	Math. 1b	Mr. Speeker	2 College Hall	1:35- 2:30	5	19
Freshmen	Ag. and W. Alg	Math. 1b	Mr. Speeker	101 Ag. Hall	3:25- 4:20	5	18
Freshmen	Ag. and W. Alg	Math. 1b	Mr. Beighle	101 Ag. Hall	9:50-10:45	5	18
Freshmen	Ag. and W. Alg	Math. 1b	Mr. Emmons	102 Ag. Hall	9:50-10:45	5	19
Freshmen	Eng. Alg	Math. 1e	Mr. Emmons	103 Ag. Hall	8:00- 8:55	5	19
Freshmen	Eng. Alg	Math. 1e	Mr. Speeker	102 Ag. Hall	8:00- 8:55	5	18
Freshmen	Eng. Alg	Math. 1e	Mr. Johnson	100 Ag. Hall	8:00- 8:55	5	17
Freshmen	Eng. Alg	Math. 1e	Mr. Johnson	2 College Hall	3:25- 4:20	5	20
Freshmen	Eng. Alg	Math. 1e	Mr. Wible	110 Ag. Hall	8:00- 8:55	5	16
Freshmen	Eng. Alg	Math. 1e	Mr. Wible	102 Ag. Hall	3:25- 4:20	5	20
Freshmen	Eng. Alg	Math. 1e	Mr. Crowe	8 College Hall	3:25- 4:20	5	19
Freshmen	Eng. Alg	Math. 1e	Mr. Robertson	301 Eng. Hall	3:25- 4:20	5	19
Sophomores	Analyt. Geom	Math. 5	Mr. Snepp	102 Ag. Hall	12:40- 1:35	5	18
Sophomores	Analyt. Geom	Math. 5	Mr. Reece	100 Ag. Hall	12:40- 1:35	5	15
Sophomores	Analyt. Geom	Math. 5	Mr. Crowe	2 College Hall	12:40- 1:35	5	17
Sophomores	Analyt. Geom	Math. 5	Mr. Johnson	2 College Hall	10:45-11:40	5	18
Sophomores	Analyt. Geom	Math. 5	Mr. Beighle	100 Ag. Hall	10:45-11:40	5	16
Sophomores	Analyt. Geom	Math. 5	Mr. Emmons	8 College Hall	10:45-11:40	5	19

Winter Term Schedule.

Class.	Subject.	No. of course.	Teacher.	Classroom.	Hour of meeting.	No. of hrs. per week.	No. of students in class.
Sub-fresh....	Geometry	Math. 2b	Mr. Beighle	2 College Hall	1:35- 2:30	5	14
Sub-fresh....	Geometry	Math. 2b	Mr. Beighle	8 College Hall	2:30- 3:25	5	11
Sub-fresh.....	Geometry	Math. 2b..	Mr. Wible	102 Ag. Hall	12:40- 1:35	5	19
Sub-fresh....	Geometry	Math. 2b	Mr. Shepp	101 Ag. Hall....	8:00- 8:55	5	15
Sub-fresh.....	Geometry	Math. 2b	Mr. Speeker	102 Ag. Hall ...	9:50-10:45	5	24
Sub-fresh.....	Geometry	Math. 2b	Mr. Speeker	103 Ag. Hall	2:30- 3:25	5	16
Sub-fresh.....	Eng. Alg	Math. 1d	Mr. Reece	101 Ag. Hall	1:35- 2:30	5	16
Sub-fresh.....	Eng. Alg	Math. 1d	*Mr. Robertson...	100 Ag. Hall	1:35- 2:30	5	16
Sub-fresh.....	Ag. and W. Alg	Math. 1a	Mr. Wible........	2 College Hall	9:50-10:45	5	13
Sub-fresh.....	Ag. and W. Alg	Math. 1a	*Mr. Robertson	8 College Hall	8:55- 9:50	5	13
Sub-fresh....	Ag. and W. Alg	Math. 1a ..	Mr. Shepp	101 Ag. Hall	8:55- 9:50	5	14
Sub-fresh.....	Ag. and W. Alg ..	Math. 1a	Mr. Shepp	8 College Hall	1:35- 2:30	5	22
Sub-fresh.....	Geometry.......	Math. 2b..	Mr. Reece	102 Ag. Hall	8:00- 8:55	5	13
Freshmen	Ag. Trig....	Math. 4a ..	Mr. Wible	100 Ag. Hall	2:30- 3:25	3	23
Freshmen	Ag. Trig	Math. 4a ..	Mr. Johnson	2 College Hall	8:55- 9:50	3	19
Freshmen	Ag. Trig......	Math. 4a	Mr. Johnson	401 Eng. Hall ...	12:40- 1:35	3	18
Freshmen.....	Ag. Trig	Math. 4a ..	*Mr. Robertson...	100 Ag. Hall.....	10:15-11:40	3	22
Freshmen.....	Ag. Trig.......	Math. 4a	*Mr. Robertson...	100 Ag. Hall......	12:40- 1:35	3	19
Freshmen.....	Ag. Trig	Math. 4a ..	Mr. Emmons ...	102 Ag. Hall	8:55- 9:50	3	20
Freshmen.....	Ag. Trig	Math. 4a	Mr. Emmons ...	2 College Hall	2:30- 3:25	3	23
Freshmen.....	Ag. Trig.	Math. 4a	Mr. Speeker	102 Ag. Hall	10:15-11:40	3	18
Freshmen.....	Ag. Trig	Math. 4a ..	Mr. Speeker.....	103 Ag. Hall	12:40- 1:35	3	19
Freshmen.....	Ag. Trig........	Math. 4a ..	Mr. Crowe	102 Ag. Hall	2:30- 3:25	3	18
Freshmen.....	Geometry.......	Math. 2c ..	Mr. Beighle	103 Ag. Hall	9:50-10:45	5	16
Freshmen.....	Geometry.......	Math. 2c	Mr. Reece	102 Ag. Hall	3:25- 4:20	5	13
Freshmen	Geometry........	Math. 2c	Mr. Wible	100 Ag. Hall	3:25- 4:20	5	14
Freshmen.....	Geometry.......	Math. 2c	Mr. Crowe	100 Ag. Hall	9:50-10:45	5	21
Freshmen	Eng. Alg........	Math. 1f...	Mr. Beighle.	8 College Hall..	3:25- 4:20	5	20
Freshmen	Eng. Alg.........	Math. 1f	Mr. Johnson	2 College Hall	8:00- 8:55	5	19
Freshmen	Eng. Alg.........	Math. 1f	*Mr. Robertson...	8 College Hall	8:00- 8:55	5	20
Freshmen.....	Eng. Alg.........	Math. 1f	Mr. Emmons. ..	103 Ag. Hall	8:00- 8:55	5	19
Freshmen.....	Eng. Alg........	Math. 1f	Mr. Emmons ...	2 College Hall..	3:25- 4:20	5	19
Freshmen.....	Eng. Alg.........	Math. 1f...	Mr. Speeker	103 Ag. Hall	3:25- 4:20	5	21
Freshmen	Eng. Alg.........	Math. 1f.	Mr. Crowe.	100 Ag. Hall	8:00- 8:55	5	22
Sophomores...	Calculus	Math. 6a	Mr. Reece	101 Ag. Hall	12:40- 1:35	5	19
Sophomores...	Calculus	Math. 6a	Mr. Johnson	2 College Hall	10:45-11:40	5	22
Sophomores...	Calculus	Math. 6a	Mr. Shepp	8 College Hall	12:40- 1:35	5	20
Sophomores...	Calculus.........	Math. 6a	Mr. Emmons	8 College Hall	10:45-11:40	5	21
Sophomores...	Calculus	Math. 6a	Mr. Crowe	2 College Hall	12:40- 1:35	5	22

*Succeeded by Mr. Fenerhak Feb. 24th, 1913.

Spring Term Schedule.

Class.	Subject.	No. of course.	Teacher.	Classroom.	Hour of meeting.	No. of hrs. per week.	No. of students in class.
Sub-fresh.....	Mensuration	3	Mr. Reece	2 College Hall	1:35- 2:30	5	16
Sub-fresh....	Mensuration	3	Mr. Speeker	8 College Hall	1:35- 2:30	5	16
Sub-fresh.....	Geometry	2c	Mr. Beighle	103 Ag. Hall	12:40- 1:35	5	20
Sub-fresh.....	Geometry...	2c	Mr. Wible	101 Ag. Hall	8:55- 9:50	5	20
Sub-fresh	Geometry.....	2c	Mr. Crowe	100 Ag. Hall	8:00- 8:55	5	21
Sub-fresh	Geometry.	2c	Mr. Shepp	8 College Hall	8:00- 8:55	5	21
Sub-fresh.....	Geometry.......	2c	Mr. Shepp	2 College Hall...	8:55- 9:50	5	19
Freshmen.....	Eng. Trig.......	4b	Mr. Wible	102 Ag. Hall ...	12:40- 1:35	5	24
Freshmen.....	Eng. Trig.......	4b	Mr. Speeker	8 College Hall	12:10- 1:35	5	24
Freshmen.....	Eng. Trig.......	4b	Mr. Fenerhak	102 Ag. Hall	8:00- 8:55	5	23
Freshmen.....	Eng. Trig.......	4b	Mr. Fenerhak	403 Eng. Hall	12:40- 1:35	5	24
Freshmen....	Eng. Trig.....	4b	Mr. Emmons	103 Ag. Hall	8:00- 8:55	5	24
Freshmen.....	Eng. Trig......	4b	Mr. Johnson	2 College Hall ..	8:00- 8:55	5	24
Sophomores ..	Calculus	6b	Mr. Reece	2 College Hall	12:40- 1:35	5	23
Sophomores ..	Calculus	6b	Mr. Beighle	103 Ag. Hall	10:15-11:40	5	17
Sophomores..	Calculus	6b	Mr. Crowe.....	8 College Hall...	10:45-11:40	5	18
Sophomores...	Calculus..........	6b........	Mr. Emmons.....	100 Ag. Hall	12:10- 1:35	5	24
Sophomores...	Calculus..........	6b.........	Mr. Johnson......	2 College Hall...	10:45-11:40	5	17

I wish to call attention to the inadequate office room for our department and also to the fact that our office has no means of ventilating except through the doors and windows.

Respectfully submitted,
MAURICE F. JOHNSON,
Acting Head of Department of Mathematics.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF ZOOLOGY AND PHYSIOLOGY.

To the President:

Sir—I have the honor to submit the following report for the Department of Zoology and Physiology and the General Museum for the year ending June 30, 1913:

As forecast in the report for last year, only two changes in the teaching staff of the department became necessary, Mr. Allen C. Conger, Ohio Wesleyan, 1910, succeeding Mr. H. S. Osler and Mr. Verne E. LeRoy replacing Mr. Royal E. Davis. Both have done excellent work and have been reengaged for the coming year. Since both had had one or more year's experience in teaching before coming here, the work of the department went on smoothly and with little or no loss of efficiency. It is a pleasure to record that all members of the force have worked earnestly and harmoniously for the best interests of the department and college and we are to be congratulated that no change in the staff is likely to occur this coming year.

The program of the department, with its three sub-divisions, zoology, physiology, and geology, involves so large an amount of laboratory work that it has been difficult at times to find proper accommodations for the many sections meeting at the same hour. At present more than half of the work is given in the new Agricultural Building and the remainder in the museum building, which necessitates the almost daily transfer of equipment, laboratory material, and museum specimens, from one building to another, and entails much additional work and some loss of time for the instructors. It is hoped that the conditions now obtaining in this respect may be materially improved in the near future.

During the coming year the advanced work in human physiology (nutrition) will be continued, as well as the veterinary physiology which has been cared for by this department during the past year. A slight change will be made in the work in general zoology by which veterinary freshmen taking this subject will cover the entire animal kingdom instead of merely the invertebrates. The elective work offered heretofore under the head of embryology, heredity and evolution, and confined to a single term, has proved so popular and valuable that it seems almost imperative that more time be given to these subjects, especially in view of the immense importance which the study of genetics has recently assumed.

This seems to be the proper time and place to renew a recommendation made several times in the past that a full year of general zoology

be required of every regular student in the agricultural course as a foundation and prerequisite for the zoological electives of the junior and senior years, which aim to give a comprehensive and well-balanced knowledge of the laws of animal life. Such required courses are almost universal in the better agricultural colleges of the United States and our own college has been most severely and justly criticised for its weakness in this particular respect. It is true that we do give our agricultural students a better course (required) in geology and mineralogy than is supplied by most similar institutions, but this does not offset the defect just pointed out.

UNIVERSITY EXTENSION WORK.

During the year much interest in the wild life of the state has been shown by the public, and the demand for copies of Michigan Bird Life has been large and constant. In accordance with the directions of the Board, complimentary copies of this book were sent to prominent scientists throughout the world, as well as to a selected list of scientific periodicals and to a few libraries. About four hundred copies were distributed in this way and an additional hundred was used for a similar list of daily and weekly newspapers and periodicals dealing largely with agriculture and rural life.

The writer has received hundreds of most appreciative letters, not only from all parts of the United States, but from a large number of foreign countries, many expressing surprise and pleasure at the character and magnitude of the work and especially at the completeness and accessibility of the information supplied. Although designed primarily for Michigan readers this book serves fairly well for any inland locality in the northern states east of the Mississippi, and teachers all over the country are finding it a convenient and helpful work of reference as well as a good laboratory manual. It has been purchased in many cases for entire classes in high schools, normal schools and colleges and the indications point to a speedy exhaustion of the edition. Thus far, however, only the cloth-bound volume has been called for to any considerable extent.

Press notices of the book, and especially the critical reviews by technical journals have been uniformly commendatory, and the only serious criticism thus far noted is the absence of a map of Michigan or of the Great Lakes Region, an omission which should be rectified if another edition is published. Of course many correspondents regret the absence of colored plates, but this was unavoidable.

Aside from the work connected with the above publication, the department has a large correspondence with teachers throughout the state and is called upon daily to give advice as to textbooks and laboratory manuals for all grades of schools, and to answer questions in natural history which teachers are unable to settle. We also serve as an information bureau for farmers and others who are often anxious to know whether certain minerals, rocks, sands, clays and marls found on their own or neighbor's lands are of economic importance. Thus during the past few months samples have been received which were supposed by the owners to be respectively gold, silver, iron, diamond, lead, zinc and copper, besides numerous samples of supposed clays, marls, molding sands, etc. Of course most of these questions belong to the State Geolo-

gist, and all seemingly important ones are so referred, but in many cases simple inspection shows the material to be common mica, iron pyrite or ordinary river sand or brick clay, and the finder is at once informed.

The writer has served for many years on the Board of Advisors of the Michigan Geological and Biological Survey, and as Secretary of the Non-Game License Commission, as well as on various lesser commissions and boards, all involving more or less time and attention. As usual a few lectures and addresses have been given during the year before schools, clubs and other organizations in different parts of the state, but press of college work has made it necessary to decline many such invitations.

THE GENERAL MUSEUM.

The General Museum serves two important purposes. It contains a large amount of valuable illustrative material which is constantly drawn upon in connection with the class work in zoology, anatomy and geology; it also serves as one of the strong attractions for college visitors, and in this way constitutes a factor of no small importance in the education of the public. From the nature of its growth its contents is necessarily of great variety and the different groups illustrated are by no means well proportioned. Formerly it included botanical specimens, models and samples of agricultural machinery, wax models of fruits, a collection of coins, and a miscellaneous assortment of more or less interesting historical relics and other curios.

As it became very crowded those entire collections which could be well placed in other departments were turned over to them and such objects as were merely curios, with little or no historical or instructional value, were placed in storage. Shorn of this extraneous material, the museum at present shows the public good examples of most of the mammals, birds, reptiles and fish of the state together with an attractive assortment of the more important minerals and rocks and a somewhat limited collection of fossils. Thousands of marine and fresh-water shells are not displayed for lack of case room, and the same is true of several thousand bird skins and eggs, and perhaps a larger number of fishes and marine animals preserved in alcohol.

It has been our aim during the past fifteen years to make the collection of Michigan animals as nearly complete as possible, believing that not only our own students, but visiting citizens of this or other states ought to be able to find here good specimens of all the animals peculiar to the Great Lakes Region. From time to time graduates and friends of the college have made us donations of important collections made in other states or even in foreign countries and these have been gladly received and placed on exhibition whenever possible. Among such donations within the past few years have been the large collection of mounted Michigan birds and mammals, from the Broas estate, prepared by the late Levi Broas of Belding; two important collections of mammals and birds from Chili, S. A., presented by D. S. Bullock of the class of 1902; and two interesting and valuable collections of the invertebrate animals of Puget Sound, Washington, made and presented by J. M. Knapp, one of the first students to attend the Michigan Agricultural College.

Occasionally, it has been possible to acquire by purchase, at a nominal

figure, important collections which would help to balance our exhibits and greatly improve the educational value of the museum. Thus during the past winter about one hundred and twenty European birds were purchased in Germany and placed on exhibition. These should be of special interest to every student of English literature since among them are good specimens of the English and European birds most frequently alluded to in literature, thus making it possible for students to compare European and American song birds, game birds, etc., and so to avoid the common mistakes which uninformed persons frequently make with regard to these birds, besides giving them a fuller appreciation of the extent and accuracy of the older British authors' observation of wild life.

It is a matter of constant regret that we are not able to employ a competent preparateur in connection with the museum, who could take care of all specimens received and also make systematic collections of fresh material for museum and laboratory. It frequently happens that we are compelled to decline the offer of valuable specimens "in the flesh" because there is no one at hand to prepare and preserve them and their condition makes it impossible to send them away to be mounted or otherwise prepared. An assistant who could do this work and also aid in part of the laboratory work in zoology and physiology would be a welcome addition to the department force and need not entail any great expense.

Under present conditions neither the curator nor any member of the teaching staff is able to give regular attention to the museum during term time and as a result we are able to do hardly more than keep the collections in passable condition and prevent deterioration, so that the museum is not by any means as useful as it might be made. In some respects our collections are the best in the state and there is no good reason why the museum, located so close to the Capital, should not be made in every respect the best.

Respectfully submitted,

WALTER B. BARROWS,

Professor of Zoology and Physiology and Curator of the General Museum.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF MILITARY SCIENCE.

The President, Michigan Agricultural College:

Sir—I submit the following as the report of the Military department for the year now closing:

The instruction, both practical and theoretical, followed closely along lines pursued last year. The new drill regulations having been in use a year gave little difficulty. The Staff class was given advanced work and at the end of the year submitted some excellent theses. The Corps deserves credit for participating with unusual attendance in the Memorial Day exercises and in the funeral of the late Professor Babcock. The congested condition of the Armory was somewhat relieved by having one company per day engage in target practice in the Post Office attic gallery.

The annual War Department inspection was made on May 6th by Captain James P. Robinson, General Staff, U. S. Army. His report has not yet been received. The exercises included regimental inspection, preceded by a review, battalion drills, company drills in close and extended order, formation of an outpost and advance and rear guards, signalling by the Signal Corps, and litter drill and first aid demonstration by the Hospital Corps detachments. All of the drills and exercises were well done and the Corps of Cadets presented an excellent appearance. Of the seven hundred eighteen cadets on the rolls but fourteen were absent, nine being reported sick.

The date of the inspection which has usually been about May 15th and which has always been objected to as too early, came earlier than ever this year, making it very difficult to show the Corps in a creditable manner. I believe the selection of the dates is left largely to the officers who make the inspection and that a protest lodged with the War Department about March first would induce them to delay two or three weeks.

In order to sustain interest until the end of the term the annual competitive drill was held several weeks later than usual. Captain R. O. Ragsdale, 3d U. S. Infantry, Inspector-Instructor, Michigan National Guard, acted as judge and awarded places as follows: first, to Company "D," Cadet Captain E. C. Spraker; second, to Company "B," Cadet Captain G. L. Lardie; third, to Company "E," Cadet Captain K. K. Vining. On the following day the Corps was reviewed by Major R. C. Vandercook, the Adjutant General of Michigan, who presented the medal to the captain of the prize company.

At the close of the year, Cadet First Lieutenant H. M. Ward, Company "M," was appointed a Third Lieutenant in the Philippine Constabulary.

Our Cadet Band, still under the efficient direction of Assistant Professor A. J. Clark, completed what was probably its most successful year. It had a larger membership than ever before and was provided with a number of fine new instruments. The Bugle Corps, also under Director Clark, was furnished with twenty-four new bugles and did very good work.

Sergeant P. J. Cross, U. S. Engineers, retired, completed his third year as assistant to the Commandant and instructor in military science, and rendered valuable assistance throughout the year.

I again renew the recommendations that have come to you year after year, viz: that better facilities for both indoor and outdoor instruction be provided at the earliest possible date. The proposal to set aside a portion of the ground to be acquired in the vicinity of the athletic field will not, in my estimation, help very much. The time lost in going and coming, taken out of a period already too short, will be serious. Furthermore, to sustain interest the ceremonies and close order drills must always be held on the present grounds, and it is impossible to have satisfactory parades so long as the central group of trees remains where it is.

I also recommend that the drill hour be increased fifteen minutes. The present period of fifty-five minutes is reduced to forty minutes of actual work, since ten minutes are used by the cadets in getting into uniform and to the drill grounds and five minutes more are lost in calling the

rolls. On account of darkness and cold the drill hour during the fall term should be the first period in the afternoon.

I recommend that the allowance for cadet officers and bandsmen of the senior class be increased from $2.25 to $3.00 per term. Very few of the seniors require the drill credits allowed but most of them find the money allowance acceptable in view of the expense involved in uniform alterations and the purchase of sabers, shoulder straps, collar ornaments, cap strap, and extra collars and gloves. I believe it would also be well to award to the captain of the prize company a medal which is to remain his personal property.

In conclusion I have to state with regret that under the new law limiting the detached service of officers of the Army, my tour at this institution comes to an end today. My experience here has been an interesting and valuable departure from Regular Army routine. I bespeak for my successor, Lieutenant J. B. De Lancey, 7th Infantry, who should report in a few days, your most generous consideration and support.

Very respectfully,

A. C. CRON,

1st Lieutenant, 10th Infantry,

Professor of Military Science and Tactics.

East Lansing, Mich., June 30, 1913.

REPORT OF THE LIBRARIAN.

President J. L. Snyder:

Dear Sir—I have the honor to present the following report on the library for the year ending June 30, 1913:

There have been added to the library during the year 1254 bound volumes of which 857 were purchased, 322 came by binding, and 75 were gifts.

For bound volumes presented to the library we are indebted as follows:

American Public Health Ass'n., 1.
American Veterinary Medical Association, 3.
Barrows, Prof. W. B., 1.
Biltmore Forest School, 1.
Connecticut, 2.
Doubleday, Page & Co., 1.
Fisk, C. K., 1.
Halligan, Prof. C. P., 1.
Indiana, 2.
Interstate Commerce Commission, 3.
Iowa, 3.
Kains, M. G., 1.
Kansas, 2.
Librarian, U. S. Dept of Agriculture, 1.
Michigan, 25.
Massachusetts, 3.
Maine, 1.
Missouri Botanical Gardens, 1.
N. Y. Central Railroad, 1.
National Lumbermen's Ass'n., 1.
Pattee, A. F., 1.
Pennsylvania, 2.
Raymond, Prof. G. L., 1.
Sanderson, R. R., 1.
Schuette, H. G., 1.
Smithsonian Institution, 3.
Tennessee, 1.
U. S. Dept. of Agriculture, 3.
Wilson, Prof. V. T., 1.
Williams & Fisher, 1.
Wisconsin, 1.
West Virginia, 1.

The large number of publications received from the Supt. of Documents is not included in the above. They are in storage in the Agricultural Building, and uncatalogued.

In the reading room are placed a large number of periodicals, both foreign and domestic, which are either purchased by the college, or received from publishers as gifts, or in exchange for our own publications.

The following is a list of exchanges and gifts from publishers:

Advocate of Peace.
Agricultural Gazette N. S. Wales.
Agricultural Journal of S. Africa.
Agricultural Ledger, Calcutta.
Agricultural Student's Gazette.
Allegan Gazette.
American Cheesemaker.
American Economist.
American Hay, Flour & Feed.
American Hereford Journal.
American Iron & Steel Institute, Bulletin.
American Issue.
American Miller.
American Perfumer.
American Poultry Advocate.
American Review of Tropical Agriculture.
American Sheep-breeder.
American Sugar Industry.
American Swineherd.
American Thresherman.
Pan-American Union.
Armada Graphic.
Australasian.
Bay City Times, Daily.
Bear Lake Beacon.
Belding Banner.
Benton Harbor News Palladium.
Berkshire World & Cornbelt Stockman.
Better Fruit.
Blue Valley Bulletin.
Buffalo Express.
Canadian Farm.
Canadian Forestry Journal.
Canadian Horticulturist.
Canal Record.
Carlisle Arrow.
Chicago Daily Farmers' & Drovers' Journal.
Christian Science Monitor.
Cincinnati Weekly Enquirer.
Clinton Republican.
Cold.
Commercial Fertilizer.
Congressional Record.
Corn.
Cosmopolitan Student.
Daily Consular Reports.
Daily Drovers' Journal & Stockman.
Dairy Record.
Dakota Farmer.
Democrat & Chronicle.
Dry Farming.
Duroc Bulletin.
Etude.
Farm and Fireside.
Farm and Home.
Farm and Ranch Review.
Farm Life and Agr'l Epitomist.
Farm Stock and Home.
Farmer and Breeder.
Farmers' Advocate.
Farmers' Guide.
Farmers' Voice.
Field and Farm.
Florists' Exchange.
Flour and Feed.
Fruit Grower.
Fruitman and Gardener.
Gleaner.
Grand Ledge Independent.
Grape Belt.
Guernsey Breeders' Journal.
Hardwood Record.
Hastings Banner.
Hawaiian Forester.
Hoard's Dairyman.
Holstein-Friesian Register.
Holstein-Friesian World.
Homestead.
Horseshoer's Journal.
Horse World.
House and Garden.

Imlay City Times.
India. Agr'l. Journal of Agr'l. Research Institute of Pusa.
Agr'l Research Institute.
Memoirs. Bacteriological Ser.
Botanical Series.
Chemical Series.
Entomological Series.
Indian's Friend.
International Institute of Agriculture. Bul. of Economics & Social Intelligence.
Italy, Societa degli Agricotori Italiana.
Jersey Bulletin.
Jewish Farmer.
Johns Hopkins University Circulars.
Journal of Agriculture, Australia.
Journal of Agriculture, Victoria.
Journal of Amer. Bankers' Ass'n.
Journal of the Board of Agr'l. and Fisheries. (London).
Journal of the College of Agriculture, Tokio.
Journal Dept. of Agriculture, S. Australia.
Kalamazoo Telegraph.
Kansas Farmer.
Kimball's Dairy Farmer.
Labor Digest.
Lansing State Journal.
Lewiston Journal.
Lincoln Freie Press.
Lister Institute of Preventive Medicine, Transactions.
Livestock Report.
Manton Weekly Tribune.
Mark Lane Express.
Market Growers' Journal.
Michigan Dairy Farmer.
Michigan Farmer.
Michigan Mirror.
Midland Naturalist.
Midland Republican.
Moderator-Topics.
Monthly Bulletin State Commission of Hort., California.
Musical Courier.
National Grange Monthly.
National Stockman and Farmer.
N. Y. Meteorology. (Draper's Hourly readings.)
N. Y. Produce Review.
Northwest Horticulturist.
Nut Grower.
Official Gazette, U. S. Patent Office.
Ohio Farmer.
Oklahoma Farm Journal.
Orange Judd Farmer.
Oregon Agriculturist.
Osceola County Herald.
Our Dumb Animals.
Owosso Press American.
Pacific Dairy Review.
Park and Cemetery.
Peru Today.
Petosky Indept. Democrat.
Philippine Agr'l. Review.
Philippine Journal of Science, Series A. B. C. D.
Poultry Keeper.
Poultry Tribune.
Practical Dairyman.
Practical Farmer.
Prairie Farmer.
Proc. Amer. Philosophical Society.
Progressive Farmer & Southern Farm Gazette.
Public Service.
Publicity Magazine.
Records of Australian Museum.
Rhodesia Agricultural Journal.
Rockefeller Institute for Medical Research. Studies.
Rural New Yorker.
Russia, Annales de l'Institut Agronomique.
Jl. for Experimentelle Landw.
Saginaw Daily News.
St. Joseph Daily Press.
Salt Lake Herald Republican.
Sao Paulo, Boletim de Agricultura.
Shepherd's Journal.
Southern Cultivator.
Southern Fruit Grower.
Special Crops.

Spokesman Review.
Standard Poultry World.
Successful Farming.
Thresherman's Review & Power Farming.
Tuscola County Advertiser.
Wallace Farmer.
West Indian Bulletin.
Western Society of Engineers, Journal.
Williamston Enterprise.
Wilson Bulletin.
Woman's Journal.
Yale Review.

The publications of the U. S. Dept of Agriculture, and the bulletins of the various experiment stations, together with the card indexes which cover them, are received and filed in the library. We also receive and file the catalogues of the leading educational institutions of the country.

The number of books drawn from the library during the year was 7886, an average of 657 books per month. The largest number, 967, were drawn in January, 1913. The smallest number, 107, in July of 1912. Fines to the amount of $24.75 were collected and placed to the credit of the library.

Our assistant, Miss Bessie Palm, has performed her duties satisfactorily and remains another year. For our student assistants, we have only words of commendation. Mr. C. B. Olney had charge of the library evenings and Sundays during the first two terms of the college year, and was succeeded by Mr. R. D. Jennings who had charge during the spring term, and who will continue with the library next year.

To the library of the Experiment Station 155 books have been added. Of these 96 were purchased, 58 came by binding, and 1 was a gift. The main library now numbers 32,729 bound volumes. The Experiment Station contains 4582 volumes. Total in both libraries, 37,311 bound volumes. This number includes all books belonging to departments, so far as they have been catalogued.

Respectfully submitted,
LINDA E. LANDON,
Librarian.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF PHYSICAL CULTURE.

To the President:

Sir—I have the honor to submit the following report of the Department of Physical Culture and Athletics for the year ending June 30, 1913.

It has been the aim to induce as large a number of students as possible to take advantage of the helpful exercise and athletic contests managed by this department. Contests between classes, dormatories, societies, etc., have been encouraged that the greatest possible number might be physically benefitted. A regular gymnasium class was held during the winter and in spite of the limited apparatus and the other poor gymnasium facilities, much interest was shown and a large num-

ber of students, from all classes, attended regularly. Cross-country running and basketball also received much attention and with the gymnasium class furnished abundant exercise for a great many during the winter months when physical exercise is almost imperative. However, this work has been materially curtailed by the absence of a suitable gymnasium and I wish to urge upon you the immediate necessity of a modern building in keeping with the general progress and standards of this college.

Teams representing the college in the various competitive sports have acquitted themselves with much credit. Under keen competition individuals have manifested loyalty to the college, gentlemanly conduct and absolute fairness at all times, and more than one contest now recorded as lost was a moral victory for the team and the college it represented.

The football team was especially strong, winning all but one game in an extremely strong schedule. The decisive victory over Ohio State University brought the college much recognition and has resulted in the further inclusion on our schedule of Wisconsin and South Dakota Universities. In basketball the college was also represented by one of the best teams in its history and again the state championship was easily won. The track and baseball teams also made excellent records, the latter with injured pitchers winning eleven out of eighteen games including Ohio State, Kentucky, and Syracuse Universities.

One of the most important athletic events was the Interscholastic Meet held here under the sanction of the Michigan Schoolmasters' Association. Nearly fifty schools were represented by over three hundred athletes. The meet was very successful and it not only aids in inducing many desirable men to enter the college but it proves of infinite value in the way of best advertising for the college.

The blanket tax, inaugurated at the beginning of the year, has fully justified its adoption. It has produced a commendable spirit in the school and has given the teams the support of the entire student body instead of the comparatively few of previous years. Because of the lessened expense it has privileged every student in the enjoyment of sport. The added income has resulted in better equipment, the formation of a "revolving fund." The students are very enthusiastic over this tax and I heartily recommend its continuance.

The following is a statement of receipts and disbursements from Sept. 22, 1912, to June 11, 1913, inclusive.

RECEIPTS.

	Fall term.	Winter term.	Spring term.	Total.
Student fees	$2,161.67	$2,053.31	$1,938.34	$ 6,153.32
Gate receipts	1,503.99	84.50	446.75	2,035.24
Season tickets	44.00	2.00	38.00	84.00
Guarantees by contracts	1,791.48	472.00	477.25	2,743.73
Miscellaneous	176.65	50.17	92.38	319.20
Totals	$5,680.79	$2,661.98	$2,992.72	$11,335.49

DISBURSEMENTS.

Refund to students	$ 10.47	$ 9.99	$ 6.50	$ 26.96
Guarantee by contracts ...	2,105.28	320.00	1,338.56	3,763.84
Officiating	540.16	65.00	110.00	715.16
Salary	187.33		5.00	192.33
Traveling expenses	758.43	745.08	732.57	2,236.08
General supplies	730.22	296.45	811.39	1,838.06
Office supplies	11.00	20.10	2.00	33.10
Printing	65.90	27.25	12.65	105.80
Loan prior to Sept. 22, 1912	200.00			200.00
Miscellaneous (a)	879.12	147.74	137.10	1,163.96
Totals	$5,487.91	$1,631.61	$3,155.77	$10,275.29
Balance June 11, 1913				$1,060.20
Balance revolving fund				$250.00

(a) Includes $300.00 set aside for "Revolving Fund."

The great number of students taking advantage of athletic training during the year made necessary the services of an assistant coach, which position Mr. I. J. Cortright has filled in a very commendable manner.

Respectfully submitted,
J. F. MACKLIN,
Director of Athletics.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DEPARTMENT OF METEOROLOGY.

President J. L. Snyder:

Dear Dr. Snyder—I have the honor to report as follows regarding the work of the Department of Meteorology for the fiscal year just closed:

Thirty-seven students elected this subject for the fall term of 1912. I believe this term's work was the most satisfactory of the three so far given. This was due largely to two causes, the use of a valuable new text book "Milham's Meteorology," and second on account of the fact that the class was smaller and the laboratory work could be carried on more successfully.

The aim has been each year to give the students a good, practical knowledge of the subject.

Very respectfully,
DEWEY A. SEELEY,
Instructor in Meteorology.

East Lansing, Mich., June 30, 1913.

METEOROLOGICAL TABLES.

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Meteorological observations for the month of July, 1912, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.)			Precipitation. (In inches and hundredths.)	Character of day.	Percentage of possible sunshine.
	Maximum.	Minimum.	Mean.			
1	81	47	64	0	Partly cloudy	92
2	86	58	72	0	Partly cloudy	95
3	85	66	76	.01	Cloudy	74
4	89	65	77	0	Partly cloudy	67
5	89	71	80	.01	Cloudy	59
6	89	69	79	.13	Cloudy	47
7	86	69	78	.08	Cloudy	77
8	89	68	78	.11	Partly cloudy	68
9	90	69	80	0	Partly cloudy	84
10	85	69	77	0	Cloudy	76
11	82	63	72	0	Partly cloudy	64
12	85	60	72	0	Partly cloudy	73
13	81	65	73	.72	Partly cloudy	30
14	86	61	74	0	Clear	77
15	85	52	68	0	Partly cloudy	60
16	78	43	60	0	Clear	100
17	84	59	72	0	Clear	100
18	67	52	60	.16	Cloudy	15
19	68	43	56	0	Partly cloudy	74
20	63	52	58	.83	Cloudy	0
21	69	60	64	.33	Cloudy	11
22	78	56	67	0	Partly cloudy	77
23	76	58	67	.04	Cloudy	37
24	84	68	76	1.56	Cloudy	45
25	82	61	72	0	Partly cloudy	61
26	74	56	65	0	Cloudy	24
27	78	52	65	0	Clear	100
28	79	60	70	.64	Cloudy	24
29	75	57	66	.01	Cloudy	56
30	75	53	64	.43	Clondy	50
31	68	48	58	0	Partly cloudy	97
Mean	30.2	59.0	69.6	Total. 5.06		62

Atmospheric Pressure.—(Reduced to sea level; inches and hundredths.)—Mean, 30.01; highest, 30.35; date, 19; lowest, 29.69; date, 24.

Temperature.—Highest, 90; date, 9; lowest, 43, date, 19; greatest daily range, 35; date, 16; Least daily range, 9; date, 21.

Wind.—Prevailing direction, southwest; total movement, 3,475 miles; average hourly velocity, 4.7: maximum velocity (for five minutes) 20 miles per hour; from south on 13.

Weather.—Number of days, clear, 4; partly cloudy, 13; cloudy, 14; on which .01 inch, or more, of precipitation occurred, 14.

Miscellaneous Phenomena (dates of).—Auroras, 0; halos: solar, 12-19; lunar, 0; hail, 0; sleet, 0; fog, 14-22; thunderstorms, 3-6-7-8-12-13-23-24-28-29-30.

*Frost.—light, 0; heavy, 0; killing, 0.

Note.—"T" indicates trace of precipitation.

*Frosts are not recorded after the occurrence of "killing." except in Florida and along the immediate coast of the Gulf of Mexico.

DEWEY A. SEELEY,
Local Forecaster, Weather Bureau.

Meteorological observations for the month of August, 1912, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.	Percentage of possible sunshine.
1	68	49	58	.01	Cloudy	80
2	65	48	56	.21	Cloudy	41
3	63	46	54	0	Cloudy	40
4	70	48	59	0	Partly cloudy	99
5	70	50	60	0	Partly cloudy	90
6	76	56	66	0	Cloudy	48
7	79	62	70	.03	Cloudy	42
8	81	64	72	.13	Cloudy	38
9	79	65	72	.13	Cloudy	19
10	76	60	68	.18	Cloudy	73
11	74	61	68	.32	Cloudy	51
12	80	60	70	.01	Partly cloudy	87
13	83	67	75	0	Clear	84
14	80	59	70	0	Clear	99
15	70	51	60	0	Clear	86
16	72	48	60	0	Clear	99
17	74	53	64	.02	Cloudy	26
18	82	65	74	.26	Cloudy	57
19	73	64	68	.50	Cloudy	17
20	83	64	74	0	Cloudy	58
21	78	59	68	0	Partly cloudy	79
22	76	56	66	.01	Partly cloudy	60
23	68	49	58	0	Partly cloudy	78
24	86	48	67	0	Clear	100
25	88	69	78	0	Clear	84
26	85	56	70	0	Clear	79
27	68	48	58	0	Clear	100
28	64	53	58	.37	Cloudy	9
29	71	52	62	0	Partly cloudy	55
30	66	47	56	.01	Cloudy	14
31	89	60	74	0	Clear	93
Mean	75.4	56.0	65.7	Total. 2.19		64

ATMOSPHERIC PRESSURE. (Reduced to sea level; inches and hundredths.)—Mean, 29.94; highest, 30.26; date, 5; lowest, 29.56; date, 22.

TEMPERATURE. Highest, 89; date, 31; lowest, 46; date, 3; greatest daily range, 38; date, 24; least daily range, 9; date, 19.

WIND. Prevailing direction, northwest; total movement, 3,729 miles; average hourly velocity, 5.0; maximum velocity (for five minutes) 22 miles per hour, from south on 28.

WEATHER. Number of days, clear, 9; partly cloudy, 7; cloudy, 15; on which .01 inch, or more, of precipitation occurred, 14.

MISCELLANEOUS PHENOMENA (dates of).—Auroras, 0; halos: solar, 22-26; lunar, 0; hail, 0; sleet, 0; fog, 19-20; thunderstorms, 8-9-10-18-25-26-28-30. *Frost: light, 0; heavy, 0; killing, 0.

NOTE. "T" indicates trace of precipitation.

*Frosts are not recorded after the occurrence of "killing," except in Florida and along the immediate coast of the Gulf of Mexico.

DEWEY A. SEELEY,
Local Forecaster, Weather Bureau.

Meteorological observations for the month of September, 1912, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.	Percentage of possible sunshine.
1	84	73	78	0	Partly cloudy	61
2	87	68	78	.12	Cloudy	73
3	81	63	72	0	Clear	89
4	83	61	72	0	Partly cloudy	56
5	91	66	78	.17	Partly cloudy	67
6	90	66	78	0	Clear	100
7	83	57	70	0	Clear	96
8	88	57	72	0	Clear	100
9	92	63	78	0	Clear	85
10	91	63	77	.08	Clear	100
11	73	50	62	.78	Clear	87
12	74	45	60	0	Clear	100
13	74	52	63	0	Cloudy	63
14	71	61	66	.05	Cloudy	19
15	70	56	63	.12	Cloudy	8
16	69	48	58	0	Clear	100
17	61	53	57	.78	Cloudy	0
18	69	50	60	.06	Cloudy	41
19	60	48	54	.03	Cloudy	23
20	71	49	60	0	Cloudy	45
21	77	58	68	.09	Partly cloudy	75
22	63	47	55	.51	Partly cloudy	32
23	71	42	56	0	Clear	98
24	71	47	59	0	Cloudy	29
25	78	51	61	0	Cloudy	45
26	54	35	44	0	Cloudy	65
27	56	32	44	0	Cloudy	61
28	46	39	42	.50	Cloudy	0
29	54	36	45	.01	Clear	100
30	58	37	48	0	Cloudy	47
Mean	73.0	52.4	62.7	Total. 3.33		63

Atmospheric Pressure.—(Reduced to sea level; inches and hundredths.)—Mean, 30.03; highest, 30.39; date, 28; lowest, 29.71; date, 18.

Temperature.—Highest, 92; date, 9; lowest, 32; date, 27; greatest daily range, 31; date, 8; least daily range, 7; date, 28.

Wind.—Prevailing direction, southwest; total movement, 3,166 miles; average hourly velocity, 4.4; maximum velocity (for five minutes) 22 miles per hour, from northwest on 5.

Weather.—Number of days, clear, 11; partly cloudy, 5; cloudy, 11; on which .01 inch, or more, of precipitation occurred, 13.

Miscellaneous Phenomena (dates of).—Auroras, 0; halos: solar, 4; lunar, 0; hail, none; sleet, 0; fog, 4-23; thunderstorms, 2-5-10-11-17-21. *Frost: light, 0; heavy, 27; killing, 0.

Note.—"T" indicates trace of precipitation.

*Frosts are not recorded after the occurrence of "killing," except in Florida and along the immediate coast of the Gulf of Mexico.

DEWEY A. SEELEY,
Local Forecaster, Weather Bureau.

Meteorological observations for the month of October, 1912, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.	Percentage of possible sunshine.
1	60	39	50	0	Clear	100
2	68	38	53	0	Clear	100
3	58	47	52	.19	Cloudy	5
4	74	46	60	0	Clear	88
5	77	42	60	0	Clear	100
6	80	55	68	0	Clear	100
7	68	36	52	0	Clear	79
8	54	34	44	.24	Cloudy	36
9	65	45	55	.52	Cloudy	9
10	56	51	54	.02	Cloudy	0
11	68	53	60	.76	Cloudy	23
12	70	40	55	.21	Partly cloudy	29
13	60	38	49	0	Clear	96
14	61	37	49	0	Clear	100
15	55	32	44	0	Clear	100
16	60	29	44	0	Clear	100
17	69	41	55	0	Clear	99
18	65	52	58	.16	Cloudy	0
19	57	33	45	0	Clear	85
20	58	29	44	0	Clear	100
21	72	42	57	0	Clear	91
22	61	43	52	.53	Cloudy	2
23	46	34	40	0	Cloudy	1
24	55	29	42	0	Clear	85
25	61	32	46	0	Clear	100
26	58	34	46	0	Clear	100
27	63	36	50	0	Partly cloudy	67
28	67	36	52	0	Partly cloudy	68
29	67	44	56	.12	Cloudy	48
30	45	31	38	0	Cloudy	0
31	39	29	34	.66	Cloudy	0
Mean	61.8	38.9	50.4	Total. 3.41		62

ATMOSPHERIC PRESSURE.—(Reduced to sea level; inches and hundredths.)—Mean, 30.06; highest, 30.48; date, 16; lowest, 29.71; date, 18.

TEMPERATURE.—Highest, 80; date, 6; lowest, 29; date, 20; greatest daily range, 35; date, 5; least daily range, 5; date, 10.

WIND.—Prevailing direction, southwest; total movement, 1,512 miles; average hourly velocity, 6.1; maximum velocity (for five minutes) 28 miles per hour, from west on 12.

WEATHER.—Number of days, clear, 17; partly cloudy, 3; cloudy, 11; on which .01 inch, or more, of precipitation occurred, 10.

MISCELLANEOUS PHENOMENA (dates of). Auroras, 0; halos: solar, 21-25-28; lunar, 0; hail, 0; sleet, 0; fog, 4-28-31; thunderstorms, 9-11-12-22. *Frost: light, 2-13-14-15; heavy, 8; killing, 16.

NOTE.—"T" indicates trace of precipitation.

*Frosts are not recorded after the occurence of "killing," except in Florida and along the immediate coast of the Gulf of Mexico.

DEWEY A. SEELEY,
Local Forecaster, Weather Bureau.

Meteorological observations for the month of November, 1912, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.	Percentage of possible sunshine.
1	37	26	32	.50	Cloudy	10
2	34	26	30	0	Cloudy	2
3	44	26	35	0	Clear	100
4	50	35	42	0	Partly cloudy	26
5	59	40	50	.21	Cloudy	69
6	53	41	47	1.02	Cloudy	0
7	48	32	40	0	Clear	79
8	52	33	42	.03	Cloudy	42
9	44	37	40	.03	Cloudy	32
10	60	38	49	0	Partly cloudy	74
11	67	47	57	0	Clear	90
12	62	52	57	.01	Cloudy	9
13	58	33	46	.59	Cloudy	0
14	33	25	29	.07	Cloudy	0
15	37	25	31	0	Clear	71
16	45	24	34	0	Partly cloudy	63
17	41	29	35	0	Cloudy	13
18	49	29	39	0	Clear	94
19	55	33	44	0	Clear	94
20	61	32	46	0	Partly cloudy	53
21	54	29	42	0	Clear	100
22	50	29	40	0	Clear	95
23	46	33	40	.08	Cloudy	27
24	33	29	31	.13	Cloudy	1
25	33	29	31	0	Cloudy	0
26	33	29	31	.13	Cloudy	0
27	30	21	26	0	Cloudy	12
28	32	19	26	0	Partly cloudy	66
29	36	29	32	0	Cloudy	11
30	48	24	36	0	Clear	100
Mean	46.1	31.1	38.6	Total. 2.86		44

Atmospheric Pressure.—(Reduced to sea level; inches and hundredths.)—Mean, 30.00; highest, 30.40; date, 30; lowest, 29.47; date, 23.

Temperature.—Highest, 67; date, 11; lowest, 19; date, 28; greatest daily range, 29; date, 20; least daily range, 4; date, 26.

Wind.—Prevailing direction, southwest; total movement, 5,664 miles; average hourly velocity, 7.9; maximum velocity, (for five minutes) 25 miles per hour, from southwest on 13.

Weather.—Number of days, clear, 9; partly cloudy, 5; cloudy, 16; on which .01 inch, or more, of precipitation occurred, 11.

Miscellaneous Phenomena (dates of).—Auroras, 0; halos: solar, 5-9-12-18-20-22; lunar, 18-20; hail, 0; sleet, 0; fog, 0; thunderstorms, 12-13. *Frost: light, 0; heavy, 0; killing, 0.

Note—"T" indicates trace of precipitation.

*Frosts are not recorded after the occurrence of "killing," except in Florida and along the immediate coast of the Gulf of Mexico.

DEWEY A. SEELEY,
Local Forecaster, Weather Bureau.

Meteorological observations for the month of December, 1912, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.	Snow on ground at 7 p. m
1	54	36	45	.06	Cloudy	0
2	53	27	40	.30	Cloudy	0
3	37	26	32	.02	Cloudy	0
4	45	32	38	.05	Partly cloudy	0
5	57	33	45	.33	Cloudy	0
6	55	28	42	.01	Cloudy	0
7	37	23	30	0	Clear	0
8	37	13	25	.05	Partly cloudy	0
9	29	16	22	0	Clear	0
10	40	26	33	0	Partly cloudy	0
11	32	9	20	0	Cloudy	0
12	17	9	13	.01	Cloudy	0.1
13	35	15	25	0	Clear	0
14	46	23	34	0	Clear	0
15	39	34	36	.04	Cloudy	0
16	37	33	35	.01	Cloudy	0
17	48	33	40	.12	Partly cloudy	0
18	36	29	32	0	Cloudy	0
19	29	25	27	.03	Cloudy	0.1
20	31	24	28	.03	Cloudy	0.9
21	26	14	20	.02	Cloudy	1.1
22	26	12	19	0	Clear	0.8
23	34	13	24	0	Partly cloudy	0.7
24	32	22	27	0	Cloudy	0.5
25	40	24	32	0	Clear	0
26	35	25	30	.02	Cloudy	0.4
27	33	24	28	0	Cloudy	0
28	41	22	32	0	Clear	0
29	40	31	36	.40	Partly cloudy	0.1
30	38	33	36	0	Cloudy	0
31	42	27	34	0	Partly cloudy	0
Mean	38.4	23.9	31.0	Total. 1.20		

ATMOSPHERIC PRESSURE. (Reduced to sea level; inches and hundredths.)—Mean, 29.95; highest, 30.41; date, 12; lowest, 29.40; date, 30.

TEMPERATURE.—Highest, 57, date, 5; lowest, 9; date, 12; greatest daily range, 27; date, 6; least daily range, 4, date, 16.

WIND.—Prevailing direction, southwest; total movement, 6,962 miles; average hourly velocity, 9.4; maximum velocity (for five minutes) 28 miles per hour, from west on 6.

WEATHER.—Number of days, clear, 7; partly cloudy, 7; cloudy, 17; on which .01 inch, or more, of precipitation occurred, 16.

MISCELLANEOUS PHENOMENA (dates of).—Auroras, 0; halos: solar, 29-31; lunar, 26; hail, 0; sleet, 0; fog, 0, thunderstorms, 0. *Frost: light ; heavy, ; killing, ——.

NOTE.—"T" indicates trace of precipitation.

*Frosts are not recorded after the occurrence of "killing," except in Florida and along the immediate coast of the Gulf of Mexico.

DEWEY A. SEELEY,
Local Forecaster, Weather Bureau.

Meteorological observations for the month of January, 1913, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.	Snow on ground at 7 p. m.
1	41	24	32	0	Partly cloudy	0
2	44	30	37	0	Cloudy	0
3	32	24	28	.01	Cloudy	0.1
4	24	16	20	0	Cloudy	0
5	29	13	21	.22	Cloudy	0
6	30	21	26	.36	Cloudy	0.2
7	26	19	22	.33	Cloudy	5.4
8	23	4	14	.05	Clear	6.0
9	25	7	16	0	Clear	5.5
10	33	15	24	.07	Cloudy	5.0
11	35	25	30	.11	Cloudy	4.2
12	25	1	13	.02	Cloudy	4.5
13	28	1	14	0	Cloudy	4.2
14	29	23	26	0	Cloudy	4.0
15	39	28	34	.01	Cloudy	2.6
16	45	36	40	.10	Cloudy	0
17	52	33	42	.02	Cloudy	0
18	33	23	28	.53	Cloudy	5.0
19	42	22	32	0	Cloudy	3.0
20	42	13	28	.95	Cloudy	6.0
21	25	6	16	0	Partly cloudy	5.5
22	37	14	26	.02	Clear	3.5
23	36	28	32	.19	Cloudy	3.0
24	37	19	28	0	Clear	2.5
25	38	21	30	0	Cloudy	2.0
26	44	23	34	0	Partly cloudy	0.2
27	23	16	20	0	Cloudy	0.2
28	25	9	17	0	Clear	0
29	32	11	22	0	Cloudy	0
30	45	27	36	.07	Partly cloudy	0
31	41	11	26	.04	Cloudy	0.2
Mean	34.2	18.2	26.2	Total. 3.10		

ATMOSPHERIC PRESSURE.—(Reduced to sea level; inches and hundredths.)—Mean, 30.02; highest, 30.64; date, 9; lowest, 29.27; date, 3.

TEMPERATURE.—Highest, 52; date, 17; lowest, 1; date, 13; greatest daily range, 30; date, 31; least daily range, 6; date, 14.

WIND.—Prevailing direction, southwest; total movement, 5,542 miles; average hourly velocity, 7.4; maximum velocity (for five minutes) 23 miles per hour, from west on 31.

WEATHER.—Number of days, clear, 5; partly cloudy, 4; cloudy, 22; on which .01 inch, or more, of precipitation occurred, 17.

MISCELLANEOUS PHENOMENA (dates of).—Auroras, 0; halos: solar, 10-13-19-21-30; lunar, 17-21-22; Hail, 0; sleet, 5-7-20; fog, 0; thunderstorms, 0. *Frost: light, 0; heavy, 0; killing, 0.

NOTE.—"T" indicates trace of precipitation.

*Frosts are not recorded after the occurrence of "killing," except in Florida and along the immediate coast of the Gulf of Mexico.

DEWEY A. SEELEY,
Local Forecaster, Weather Bureau.

Meteorological observations for the month of February, 1913, at Agricultural College, East Lansing, Michigan.

Date.	Temperature.—Degrees Fahrenheit. Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.	Snow on ground at 7 p. m.
1	16	9	12	.01	Partly cloudy	0.3
2	21	7	14	0	Clear	0.2
3	32	16	24	.01	Partly cloudy	0.1
4	18	1	10	.01	Partly cloudy	0.1
5	13	-1	6	.01	Cloudy	0.2
6	16	3	10	.01	Cloudy	0.2
7	18	9	14	.02	Cloudy	0.3
8	26	12	19	.01	Partly cloudy	0.1
9	30	8	19	0	Partly cloudy	0
10	31	8	20	.01	Partly cloudy	0.1
11	33	9	21	0	Partly cloudy	0.1
12	13	2	8	0	Clear	0
13	21	3	12	0	Clear	0
14	38	15	26	0	Clear	0
15	42	14	28	.07	Cloudy	0.2
16	26	11	18	.01	Cloudy	0.1
17	29	18	24	0	Cloudy	0
18	39	18	28	0	Partly cloudy	0
19	57	34	46	0	Cloudy	0
20	48	29	38	.17	Cloudy	0
21	30	24	27	.73	Cloudy	5.0
22	33	20	26	.23	Cloudy	5.0
23	21	6	14	0	Clear	5.0
24	18	-4	7	0	Clear	4.8
25	25	12	18	0	Clear	4.0
26	35	22	28	.32	Cloudy	5.5
27	28	20	24	.03	Cloudy	6.0
28	25	13	19	0	Clear	5.5
Mean	27.9	12.1	20.0	Total. 1.65		

ATMOSPHERIC PRESSURE.—(Reduced to sea level; inches and hundredths.)—Mean, 30.04; highest, 30.45; date, 12; lowest, 29.56; date, 22.

TEMPERATURE.—Highest, 57; date, 19; lowest, -4; date, 24; greatest daily range, 28; date, 15; least daily range, 6; date, 21.

WIND.—Prevailing direction, southwest; total movement, 5,984 miles; average hourly velocity, 8.9; maximum velocity (for five minutes) 23 miles per hour, from southwest on 7.

WEATHER.—Number of days, clear, 8; partly cloudy, 8; cloudy, 12; on which .01 inch, or more, of precipitation occurred, 15.

MISCELLANEOUS PHENOMENA (dates of).—Auroras, 0; halos: solar, 0; lunar, 18; hail, 0; sleet, 21-22; fog, 0; thunderstorms 0. *Frost: light, 0; heavy, 0; killing, 0.

NOTE.—"T" indicates trace of precipitation.

*Frosts are not recorded after the occurrence of "killing," except in Florida and along the immediate coast of the Gulf of Mexico.

DEWEY A. SEELEY,
Local Forecaster, Weather Bureau.

Meteorological observations for the month of March, 1913, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.	Snow on ground at 7 p. m.
1	30	15	22	.08	Partly cloudy	5.0
2	15	4	10	.02	Partly cloudy	5.0
3	34	10	22	.14	Cloudy	5 5
4	27	0	14	.06	Partly cloudy	6.3
5	31	-1	15	.06	Cloudy	6.3
6	15	-2	6	0	Partly cloudy	6.3
7	21	-10	6	0	Clear	6.0
8	42	13	28	0	Partly cloudy	4.2
9	43	28	36	0	Partly cloudy	2.0
10	39	23	31	0	Partly cloudy	1.0
11	43	26	34	0	Clear	0.5
12	54	31	42	0	Clear	0
13	61	38	50	.04	Partly cloudy	0
14	67	38	52	.10	Partly cloudy	0
15	38	20	29	0	Cloudy	0
16	28	17	22	.10	Cloudy	0
17	36	5	20	.02	Partly cloudy	0 2
18	57	36	46	0	Clear	0
19	63	38	50	.01	Clear	0
20	62	32	47	.01	Cloudy	0
21	56	20	38	.51	Cloudy	0.1
22	32	19	26	.02	Clear	0
23	53	28	40	1.09	Cloudy	0
24	61	33	47	.42	Cloudy	0
25	33	24	28	.24	Cloudy	0
26	28	21	24	.36	Cloudy	1.7
27	30	13	22	.04	Partly cloudy	6 0
28	35	11	23	0	Partly cloudy	4 5
29	47	30	38	0	Partly cloudy	0
30	59	39	49	.24	Partly cloudy	0
31	50	35	42	.20	Partly cloudy	0
Mean	41.6	20.5	31.0	Total. 3.76		

ATMOSPHERIC PRESSURE.—(Reduced to sea level; inches and hundredths.)—Mean, 30.00; highest, 30.61; date, 22; lowest, 29.06, date, 21.

TEMPERATURE.—Highest, 67; date, 14; lowest, -10; date, 7; greatest daily range, 36; date, 21; least daily range, 7; date 26.

WIND.—Prevailing direction, southwest; total movement, 7,323 miles; average hourly velocity, 9.8; maximum velocity (for five minutes) 37 miles per hour, from southwest on 24.

WEATHER.—Number of days, clear, 6; partly cloudy, 15; cloudy, 10; on which .01 inch, or more, of precipitation occurred, 20.

MISCELLANEOUS PHENOMENA (dates of).—Auroras, 0; halos: solar, 4-5-10-13-17-29; lunar, 16; hail, 23-24; sleet, 21-25-26; fog, 0; thunderstorms, 14-23-24-30. *Frost: light, 0; heavy, 0; killing, 0.

NOTE.—"T" indicates trace of precipitation.

*Frosts are not recorded after the occurrence of "killing," except in Florida and along the immediate cost of the Gulf of Mexico.

DEWEY A. SEELEY,
Local Forecaster, Weather Bureau.

Meteorological observations for the month of April, 1913, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.	Percentage of possible sunshine.
1	55	33	44	0	Clear	98
2	47	37	42	.35	Cloudy	0
3	65	40	52	.89	Cloudy	12
4	60	34	47	.29	Cloudy	9
5	41	30	36	0	Partly cloudy	71
6	47	29	38	0	Clear	100
7	40	28	34	0	Partly cloudy	56
8	47	24	36	0	Partly cloudy	85
9	44	32	38	.05	Cloudy	2
10	55	38	46	.49	Cloudy	0
11	52	40	46	.01	Cloudy	0
12	42	36	39	0	Cloudy	0
13	53	35	44	0	Clear	100
14	50	30	40	0	Clear	100
15	61	28	44	0	Clear	100
16	63	36	50	0	Clear	100
17	69	32	50	0	Clear	100
18	72	39	56	0	Clear	100
19	54	29	42	0	Clear	98
20	50	22	36	0	Clear	100
21	59	30	44	0	Partly cloudy	82
22	78	50	64	.15	Cloudy	74
23	78	57	68	0	Clear	94
24	79	51	65	0	Partly cloudy	79
25	63	44	54	.34	Cloudy	19
26	47	36	42	.23	Cloudy	1
27	44	31	38	.27	Cloudy	0
28	54	37	46	.03	Partly cloudy	68
29	58	34	46	0	Clear	100
30	71	35	53	0	Clear	100
Mean	56.6	35.2	45.9	Total. 3.10		62

ATMOSPHERIC PRESSURE.—(Reduced to sea level; inches and hundredths.)—Mean, 30.08; highest, 30.55; date, 20; lowest, 29.64; date, 4.

TEMPERATURE.—Highest, 79; date, 24; lowest, 2; date, 20; greatest daily range, 37; date, 17; least daily range, 6; date, 12.

WIND.—Prevailing direction, northeast; total movement, 6,206 miles; average hourly velocity, 8.6; maximum velocity (for five minutes) 29 miles per hour, from northeast on 28.

WEATHER.—Number of days, clear, 13; partly cloudy, 6; cloudy, 11; on which .01 inch, or more, of precipitation occurred, 11.

MISCELLANEOUS PHENOMENA (dates of).—Auroras, 0; halos: solar, 8-21-22; lunar, 0; hail, 22; sleet, 0; fog, 27; thunderstorms, 2-3-4-22-25. *Frost: light, 19-27-29-30; heavy, 0; killing, 15-17-20-21.

NOTE.—"T" indicates trace of precipitation.

*Frosts are not recorded after the occurrence of "killing," except in Florida and along the immediate coast of the Gulf of Mexico.

DEWEY A. SEELEY,
Local Forecaster, Weather Bureau.

Meteorological observations for the month of May, 1913, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.	Percentage of possible sunshine.
1	81	47	64	0	Clear	100
2	83	52	68	0	Clear	100
3	82	58	70	0	Clear	95
4	81	61	71	0	Partly cloudy	80
5	75	58	66	.21	Cloudy	52
6	66	40	53	.01	Partly cloudy	76
7	61	33	47	0	Clear	100
8	65	39	52	0	Cloudy	57
9	55	33	44	0	Clear	100
10	54	27	40	0	Clear	100
11	60	29	41	0	Clear	100
12	65	38	52	.01	Cloudy	62
13	71	44	58	.29	Cloudy	66
14	62	48	55	.30	Cloudy	36
15	76	46	61	.27	Cloudy	48
16	64	49	56	0	Partly cloudy	69
17	72	47	60	.08	Partly cloudy	75
18	62	44	53	0	Clear	96
19	62	37	50	0	Clear	82
20	61	50	56	0	Cloudy	8
21	76	50	63	.18	Cloudy	23
22	59	50	54	0	Cloudy	0
23	59	47	53	.05	Cloudy	13
24	68	47	58	.01	Partly Cloudy	63
25	55	39	47	0	Cloudy	9
26	52	37	44	.23	Cloudy	0
27	68	45	56	.01	Clear	81
28	79	44	62	0	Clear	100
29	68	54	61	.09	Cloudy	25
30	68	51	60	.43	Partly cloudy	36
31	73	53	63	0	Partly cloudy	60
Mean	67.2	45.1	56.2	Total. 2.22		61

ATMOSPHERIC PRESSURE.—(Reduced to sea level; inches and hundredths.)—Mean, 30.04; highest, 30.51; date, 10; lowest, 29.72; date, 21.

TEMPERATURE.—Highest, 83; date, 2; lowest, 27; date, 10; greatest daily range, 35; date, 28; least daily range, 9; date, 22.

WIND.—Prevailing direction, southwest; total movement, 4,436 miles; average hourly velocity, 6.0; maximum velocity (for five minutes) 24 miles per hour, from southwest on 3.

WEATHER.—Number of days, clear, 11; partly cloudy, 7; cloudy, 13; on which .01 inch, or more, of precipitation occurred, 14.

MISCELLANEOUS PHENOMENA (dates of).—Auroras, 0; halos: solar, 5-9-12-13-17, lunar, 0; hail, 0; sleet, 0; fog, 31; thunderstorms, 5-12-14-15-17-21-30. *Frost: light, 12; heavy, 7; killing, 10-11.

NOTE.—"T" indicates trace of precipitation.

*Frosts are not recorded after the occurrence of "killing," except in Florida and along the immediate coast of the Gulf of Mexico.

DEWEY A. SEELEY,
Local Forecaster, Weather Bureau.

Meteorological observations for the month of June, 1913, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.	Percentage of possible sunshine.
1	81	52	66	0	Partly cloudy	78
2	73	43	58	0	Clear	100
3	80	49	64	0	Clear	97
4	71	43	57	0	Clear	100
5	75	45	60	0	Clear	82
6	88	59	74	.12	Cloudy	67
7	59	39	49	.08	Cloudy	41
8	58	35	46	0	Clear	100
9	64	34	49	0	Clear	100
10	70	34	52	0	Clear	100
11	77	41	59	0	Clear	100
12	80	42	61	0	Clear	98
13	83	50	66	0	Clear	100
14	87	51	69	0	Clear	100
15	90	65	78	0	Clear	100
16	95	66	80	.15	Clear	66
17	86	59	72	0	Clear	100
18	84	56	70	0	Partly cloudy	91
19	90	62	76	.09	Cloudy	49
20	82	62	72	.53	Cloudy	29
21	71	54	62	0	Cloudy	43
22	77	50	64	0	Clear	99
23	81	52	66	0	Clear	100
24	87	59	73	0	Cloudy	87
25	90	67	78	0	Partly cloudy	77
26	91	70	80	0	Partly cloudy	68
27	95	70	82	0	Clear	96
28	91	69	80	0	Clear	100
29	92	67	80	0	Partly cloudy	86
30	98	66	82	.04	Partly cloudy	52
Mean	81.5	53.7	67.6	Total. 1.01		83

ATMOSPHERIC PRESSURE.—(Reduced to sea level; inches and hundredths.)—Mean, 30.05; highest, 30.62; date, 10; lowest, 29.81; date, 30.

TEMPERATURE.—Highest, 98; date, 30; lowest, 34; date, 9; greatest daily range, 38; date, 12; least daily range, 17; date, 21.

WIND.—Prevailing direction, southwest; total movement, 3,538 miles; average hourly velocity, 4.9; maximum velocity (for five minutes) 22 miles per hour, from northwest on 6.

WEATHER.—Number of days, clear, 18; partly cloudy, 6; cloudy, 6; on which .01 inch, or more, of precipitation occurred, 6.

MISCELLANEOUS PHENOMENA (dates of).—Auroras, 0; halos: solar, 0; lunar, 0; hail, 0; sleet, 0; fog, 0; thunderstorms, 6-7-16-19-20-30. *Frost: light, 8-9-10; heavy, 0; killing, 0.

NOTE.—"T" indicates trace of precipitation.

*Frosts are not recorded after the occurrence of "killing," except in Florida and along the immediate coast of the Gulf of Mexico.

DEWEY A. SEELEY,
Local Forecaster, Weather Bureau.

REPORT OF THE MICHIGAN WEATHER SERVICE FOR THE FISCAL YEAR ENDING JUNE 30, 1913.

This service has continued in operation along the same general lines that have marked its administration for some years past.

In a general way it may be stated that these lines of endeavor are:

(1) The general collection and compilation of meteorological data at more than one hundred points in the state. The principal items of data collected and compiled are temperature, precipitation, prevailing wind direction and general character of the sky as regards cloudiness.

(2) The dissemination of the daily forecasts and frost and cold wave warnings. Michigan now has a very valuable asset in the form of twenty-five years' observations which cover the state not as well as is desirable, but in such a way as to give a general and rather intimate knowledge of its climatic characteristics for the period covered.

The work of the Director of the Service has increased enormously during the past ten years, although the number of stations is not much greater than it was a decade ago.

Primarily, the administration of one hundred stations requires considerable labor, as it involves the selection of voluntary observers, which in itself, is a difficult matter.

After an observer has been secured, he must be kept supplied with instruments, stationery and instructions for carrying on his work and when his reports are received, they are carefully scrutinized, corrected, if necessary, and then compiled at monthly intervals.

The use of these observations is becoming greater with every year. Meteorological statistics are intimately related with almost every line and phase of human endeavor and in recent years have been extensively used in the extension of Michigan's resources in agriculture. The agriculturist and horticulturist are demanding more and more information about climate.

The rapid development of the water power resources of Michigan have also entailed much reference to the records of the Michigan Weather Service and it may be said parenthetically that the water power possibilities of Michigan have hardly been touched, although there are now in operation many large projects.

Another very important phase of reference to our records is the legal one; our records are being brought into court more and more as illuminating facts that in hundreds of cases are vital to a just and intelligent decision.

All told, the correspondence involved in these many phases has become enormous.

The use of the weather forecast is much more general than in the past. As related in my preceding report, the extension of telephone service to rural communities has made it possible for a majority of the more progressive farmers of the state to get the forecast each day by simply calling up their "central" between 10:00 and 11:00 a. m.

It is also worthy of note that the farmer is beginning to appreciate the value and benefit of the weather forecast and, at critical times, to regulate his outdoor operations accordingly. There is perhaps no other profession of civilization that is so vitally interested not only in actual weather conditions, but in coming weather conditions, as the farmer. He meets the weather every day and all of the day.

In addition to this, the modern progressive farmer is also using our statistics in getting a better understanding of what crops to grow and of when to plant them. Twenty-five years' record of the last killing frost in fall is of untold benefit to the corn grower, because the average date is the safe date, although there may be years that are not average. Nevertheless, as in any other business, it is the average condition not for one year, but for many years, that spells success or failure.

All of the principal telephone companies of the state now distribute promptly and regularly the Weather Bureau forecast and the information that they have at their various "centrals" can be secured by any one having a telephone simply for the asking.

C. F. SCHNEIDER,
Director.

Grand Rapids, Mich., June 30, 1913.

REPORT OF STATE INSPECTOR OF NURSERIES AND ORCHARDS.

To the State Board of Agriculture:

Gentlemen—For a number of years there has been an increase in the amount of work this department has been called upon to do. This has been due in part to the marked interest being taken in fruit growing in all parts of the state. This has led to numerous calls for assistance in controlling outbreaks of dangerous insects and diseases.

The San Jose scale gave less trouble than in former years, which may have been partly due to the cold, wet summer, but it was undoubtedly the long continued and extremely cold periods during the winter of 1911-12 that had most to do in lessening the numbers, as when the spring opened a very large per cent of the scales on the trees were dead.

While a large part of the spraying done in the state last year was very imperfect, in a considerable proportion of the orchards most excellent work was done and as a result it was practically impossible to find any live scales on the trees, even though they had been badly infested in previous years.

NURSERY INSPECTION.

There has been very little change in the number of nurseries and the amount of nursery stock to be inspected. As a result of the efforts that have been made to clean up the old blocks and to remove thorn and seedling apples and plums from the fence rows the stock in most of the nurseries was in unusually good shape and, as most of the stock was sprayed several times during the season, the trees were very generally free from dangerously infectious diseases and insects.

The climatic conditions seemed unusually favorable for the development of the apple-tree aphis and woolly aphis, but by persistent spraying with tobacco decoctions they were prevented from causing any serious harm. The addition of one cake of hard soap, or a pint of whale-oil soap to 50 gallons increased the efficiency of the spray.

In most of the nurseries crown-gall was less troublesome than in other years. Although it is not possible to make a very careful inspection before the trees are dug, all nurserymen are instructed to destroy trees infested with this disease and to avoid using the same land for growing two consecutive crops of trees of the same general nature.

FOREIGN NURSERY STOCK.

In October, 1912, the U. S. Plant Quarantine act went into effect and in accordance with its terms importers of nursery stock are required to take out a permit and duplicate notices of the arrival must be sent to the Federal Horticultural Board and to the inspector of Nurseries of the state to which the stock is consigned. Most of the stock brought into Michigan is from France, Belgium and Holland. In the fall it consists largely of azaleas and other shrubs for greenhouse forcing. Later on, the bulk of the shipments are made up of apple, pear, plum and cherry seedlings to be used as stocks by nurserymen. Many thousand maple and other shade trees, evergreens and shrubs of small sizes for growing in the nurseries are also imported. As spring comes on the importations include hardy rhododendrons and box and bay trees for porch decoration.

The object of the U. S. Plant Quarantine law is to prevent the introduction of dangerous insects and diseases, and an embargo has been placed upon certain species of trees, etc., as for instance, the five-needle pines, which are likely to be infected with the "white-pine rust," but for the most part nursery stock is admitted provided it is accompanied by a certificate of inspection. Even then, however, the danger from the introduction of certain insects is so great that the stock from Western Europe is re-inspected after it arrives in this country.

The gypsy moth and brown-tail moth are especially feared. In former years, before the passage of the U. S. Plant Quarantine law, as many as 10,000 larvae of the brown-tail moth, contained in twenty-five nests, were found upon the trees in a single box of nursery stock consigned to a Michigan point. So far as is known neither of these insects has been able to secure a foothold in Michigan, but eternal vigilance will be needed to keep them out. For a number of years they have caused immense losses in Eastern New England, where $1,000,000 annually is spent in fighting them. A quarantine exists against that section to the extent that all shipments of nursery stock have to pass a special inspection for the presence of these insects.

During the fall, winter and spring months, the brown-tail moth is in the form of small larvae, perhaps one-eighth of an inch long, which are enclosed in silken nests attached to the branches. These closely resemble the cocoons of some of the larger moths.

At this same period the gypsy moth is in the egg stage. These will be found in flattened patches an inch or a little more in diameter, upon the stems and larger branches. The eggs resemble small pearls and

are covered with a large number of rather coarse, tawny hairs. The larvae of both insects reach their full development about the first of July, when they are nearly two inches in length. The gypsy moth larvae are very easy to distinguish as they have a double row of tubercles along their backs. The five front tubercles in each row are blue and the six at the rear are red. The brown-tail larvae have a row of white spots on each side of the body.

As the introduction of both of these insects is greatly to be feared, any one finding specimens of insects resembling the above description should send them in to the department for identification.

INSECTICIDES AND FUNGICIDES.

In order that manufacturers of spraying materials shall guarantee their strength so that the fruit grower may know what he is buying, acting under Act 91, P. A. 1909, the manufacturers have been compelled to file statements and sample labels in which the percentages of the essential ingredients are guaranteed, and a permit for their sale in Michigan is then issued.

The National Insecticide Act of 1910 has the same object in view but only deals with such insecticides and fungicides as enter into interstate commerce. As there are a half-dozen firms in Michigan which manufacture insecticides and fungicides in large quantities, besides as many more doing a small business, none of whose products sold within the state come under the control of the United States authorities, it is highly important, owing to the immense quantities used in Michigan, that the work of supervision be kept up.

Lime-sulphur solution and arsenate of lead are the kinds most extensively used, and especial attention has been paid to them.

Bordeaux mixture is also made on a large scale by several firms but the use of the commercial brands by fruit growers has been discouraged as, besides being considerably more expensive than if home made, with the same amount of copper hydrate, its use has not been generally satisfactory, and in fact as compared with home made Bordeaux used at the same time and in the same way, it has been demonstrated that while the latter will give comparative freedom from such troubles as late blight of the potato and black rot of the grape, the results with the commercial brands of Bordeaux mixture have been but little better than where no spraying whatever was done.

In passing upon the labels an endeavor has been made to secure uniformity in the statements and the terms used in the analyses so that they can be compared.

"PEACH YELLOWS" AND "LITTLE PEACH."

Owing to the fact that a large number of the older peach orchards in the district where "peach yellows" and "little peach" have been most troublesome have been very largely destroyed either by the winter or other causes, the loss from the above diseases has been less noticeable.

A careful watch of the orchards has been kept, particularly in Newaygo and southern Mason counties, in order that the further spread of the diseases northward might be checked. As a result of this, practically no advancement has been noticed. In the more southern counties there

has been almost a clean sweep of the orchards and those who now have old trees should not neglect to watch them carefully and if the orchards are infected with either disease, they should be removed at once. By thus cleaning out every vestige of the diseases the chances of growing new orchards will be greatly increased.

Fruit growers in the counties from Mason to Berrien have now had the fact, that the "yellows" is a very dangerous disease, very forcibly impressed upon them and these lessons should be sufficient to bring about the utmost care and thoroughness in fighting them. The experience of the last forty years has demonstrated that if diseased trees are allowed to remain in an orchard, all of the trees will be quickly wiped out but if they are removed as soon as the diseased fruit is found on the trees the loss will be very small. From the fact that there is danger of infection from orchards within a radius of perhaps one mile, it is very important that the action be concerted and that townships in which these diseases prevail should have orchard inspectors to see that everyone promptly complies with the law.

Until within the last three or four years these diseases have been confined to the western part of the state but they have now developed to quite a considerable extent in Oakland and Macomb counties and as the fruit growers of those sections generally are not familiar with the diseases it is particularly important that competent persons are selected in each township where peaches are extensively grown so that the spread of the diseases may be checked.

CROWN GALL OF THE PEACH.

During the past two or three years this disease has been quite troublesome in several of the nurseries, but from the fact that the inspection must be done while the trees are growing it is not possible to determine the presence of crown gall on the roots.

Nurserymen have been instructed to throw out all trees infected with the crown gall and most of them are evidently trying to live up to the requirement. However, in the rush of packing, infected trees are frequently sent out and the purchasers are advised to discard all such trees, especially when the galls are upon the collar or main roots. If the number infected is sufficiently large to make claims for damages worth while, all responsible nurseries should be willing to refund the amount paid provided due notice is given and the trees are placed subject to their order.

Crown gall is also of a contagious nature and although it is not likely to spread from tree to tree in the orchard, it evidently spreads from raspberries growing in peach orchards, hence it is not advisable to plant raspberries between the rows of peach trees. While cases have been noticed in which trees having galls upon the collar or main roots have apparently recovered from the disease, it more generally happens that a gall upon the main root of a peach tree will involve a larger surface and practically girdle a tree, rendering it of no value.

SAN JOSE SCALE.

The area infested by this insect has not appreciably changed during the year. The northern part of the state as yet appears to be entirely

free from it. Throughout the southern part of the state there are many thousands of trees in unsprayed orchards which are dead or dying but commercial fruit growers are suffering little from it as they are able to hold the insect in check. As was predicted when the insect first appeared, many are finding it is a blessing in disguise as the thorough spraying of the trees required to control the scale also destroys other dangerous insects and diseases. A fruit grower who is thus able to control the scale, being obliged to have a suitable outfit for that purpose and having impressed upon him the importance of thorough work, is better prepared to fight the insects and fungous diseases which develop during the summer.

There has been no particular progress in the fighting of this insect during the year. The better grades of commercial lime-sulphur solution which contain 20 per cent and upwards of sulphur, if used at the rate of one part to eight of water just before growth starts in the spring, will very thoroughly clean up the trees. Attention, however, is called to the value of summer spraying in cases where the spring spraying was neglected or was not thoroughly done. The first brood of young appears from July 1st to 15th, and an application of two gallons of lime-sulphur solution in fifty gallons of water at the time most of the young have appeared will destroy them. This can be used without danger of serious injury except upon peaches and Japanese plums, where care should be taken to spray the branches only. By using a fine mist and only applying enough to cover the branches the injury will be lessened. Applications made upon clear days when the spray will quickly evaporate will also be less harmful than upon cloudy days.

The following list contains the names of those who were licensed to handle nursery stock during the year 1912-13.

Respectfully submitted,

L. R. TAFT,

State Inspector of Nurseries and Orchards.

East Lansing, Mich., June 30, 1913.

LIST OF NURSERIES LICENSED FOR YEAR ENDING JULY 31, 1913.

MICHIGAN NURSERIES.

Allen Bros., Paw Paw.
Au Sable Forest Nursery, Lovells.
Allis and Hood, Adrian.
Baldwin, O. A. D., Bridgman.
Bashford, C. L., Mason.
Berrydale Experiment Gardens, Holland.
Bigelow, J. N., Bangor.
Blake, Wm., Buchanan.
Boehringer Brothers, Bay City.
Bragg & Co., L. G., Kalamazoo.
Pridgman Nursery Co., The Geo. W., Benton Harbor.
Brown, Douglas M., Grand Rapids.

Buskirk, J. D., Shelby.
Celery City Nursery Co., Kalamazoo.
Collins, W. E., Fennville.
Coryell, R. J., Birmingham.
Cole, Levant, Battle Creek.
Cross, J. A., Spring Lake.
Cukerski, Wencel L., Grand Rapids.
Culver, O. B., Colon.
Cutler & Downing, Benton Harbor.
Daly, Thos. W., Watervliet.
Dean, Geo. N., Shelbyville.
Detroit Nursery Co., Detroit.
Dressel, G. L., Frankfort.
Dunham, Enos W., Baroda.
Elliott, Hanson B., Harbor Springs.
Evergreen Cemetery, Chicago, Ill.
Ferrand and Son, E., Detroit.
Fisher, Guyon, Fennville.
Flansburgh & Son, C. N., Jackson.
Flansburgh & Potter Co., Leslie.
Genesee County Nurseries, Flint.
Glenwood Nurseries, Holland.
Greening Nursery Co., Monroe.
Gustin, Chas. F., Adrian.
Hamilton & Sons, A., Bangor.
Havekost, G. H., Monroe.
Hawley, G. A., Hart.
Hawley, H. E., South Haven.
Helmer Farm Nursery, Battle Creek.
Hibbler, E. B., Detroit.
Hunziker, M. J., Kent City.
Husted, N. P., Lowell.
Ilgenfritz Sons' Co., I. E., Monroe.
Insulinda Nurseries, Kalamazoo.
Jackson, James, Kalamazoo.
Jeffrey, James Sr., Kalamazoo.
Kalamazoo Nurseries, Kalamazoo.
Katzenberg, Valentine, Saginaw.
Kellogg Co., R. M., Three Rivers.
Knight & Son, David, Sawyer.
Lanphear Brothers, Hartford.
Lohrman Seed Co., Detroit.
Lock, Daniel, Union Pier.
Mack, Frank H., Hart.
Marvin, O. F., Holton.
Maudlin Nursery Co., E., Bridgman.
Mayer, Michael, Jr., Merrill.
McCormick, N. L., Montrose.
McCormick Nursery Co., Monroe.
Merrifield Brothers, Bloomingdale.
Michigan Nursery Co., Monroe.
Miller, Abner, Fennville.

Miller, J. W., Fremont.
Munson, Wm. K., Grand Rapids.
Myers, P. J., Bridgman.
Mutual Nurseries, Monroe.
Nash, Chas. C., Three Rivers.
Nehmer & Sons Co., Daniel, Ontonagon.
Nelson & Son, J. A., Paw Paw.
Newell, Reuben, Highland Park.
Orchard Lake Nurseries, Orchard Lake.
Pier, Frank D., Evart.
Pilkinton & Son, S. H., Portland.
Pitcher, W. D., Buchanan.
Pontiac Nursery Co., Detroit.
Prestage, J. G., Allegan.
Powers & Son, Charles, Douglas.
Prudential Nursery Co., Kalamazoo.
Retz, Mathias, Riverside.
Rice, Greta B., Port Huron.
Rokely, J. N., Bridgman.
Schild, H. J., Ionia.
Sheldon, Asa G., Paw Paw.
Singer, W. H., Lapeer.
Smith, Henry, Grand Rapids.
Smith, R. E., Woodville.
Speyers, Chas. M., Ypsilanti.
Spielman Brothers, Adrian.
Stahelin, Fred C., Bridgman.
Star Nursery, The, Big Rapids.
Stephens, John S., South Haven.
Thrasher, C. D., Hamburg.
Trescott, C. P., Paw Paw.
Voorhees, C. W., Buchanan.
Westmacott, Harry S., Montague.
Weston & Co., A. R., Bridgman.
Whitten, C. E., Bridgman.
Wildemere Gardens, Royal Oak.
Wise, Ralph, Plainwell.
Wolverine Co-operative Nursery Co., The, Paw Paw.
Wolverine Nurseries, The, Detroit.

LICENSED MICHIGAN DEALERS.

Alferink, Albert, Holland.
Asman & Dunn, Detroit.
Augustine, L. D., St. Joseph.
Barnes, C. A., Jackson.
Beattie, Thos., Detroit.
Cross, Eli, Grand Rapids.
Crowley, Milner Co., The, Detroit.
Davison Nursery Co., Davison.
Davis, S. B., Jackson.
Day, Edmund, Jackson.
Field Co., L. H., Jackson.

Freyling and Mendels, Grand Rapids.
Gibson, S. B., Detroit.
Gill, B. M., Ypsilanti.
Grand Rapids Nursery Co., Grand Rapids.
Healy, Wm., Bloomingdale.
Hotchkiss, C. J., Detroit.
Hudson Co., The J. L., Detroit.
Jones, Sons & Co., J. R., Kalamazoo.
Kingsbury, Lathrop, Muskegon.
Knapp, Wm. F., Monroe.
Kresge Co., S. S., Detroit.
Merrill, W. F., South Haven.
Northwestern Nurseries, Traverse City.
Pearson & Co., D. S., Grand Rapids.
Radewald, Otto, Niles.
Rasmussen, R. J., Marlette.
Richardson, O. I., Detroit.
Scott, C. H., Traverse City.
Slanker, Frank, Benton Harbor.
Stover, F. J., Traverse City.
Strittmatter, A., Detroit.
Sweet, L. H., McGregor.
Tossy, L. F., Detroit.
Trankla & Co., Chas., Grand Rapids.
Wade, B. M., Saugatuck.
Walthers' Dept. Store, Bay City.
Westgate Nursery, The H. L., Monroe.
Winkworth, R. M., Detroit.
Woolworth, F. W., Detroit.

LIST OF FOREIGN NURSERIES.

Allen Nursery Co., Rochester, N. Y.
Bogue, Nelson, Batavia, N. Y.
Brown Brothers' Company, Rochester, N. Y.
Bryant & Son, A., Princeton, Ill.
Bryant Brothers, Dansville, N. Y.
Cartwright, I. D., Toledo, Ohio.
Carlton Nursery Co., Rochester, N. Y.
Chase, Chas. H., Rochester, N. Y.
Chase Nurseries, Geneva, N. Y.
Clyde Nursery, The, Clyde, Ohio.
Costich, G. A., Rochester, N. Y.
Davis Nursery Co., Franklin, Baltimore, Md.
Dreer, Henry A., Philadelphia.
Empire State Nursery Co., Waterloo, N. Y.
Fairview Nurseries, Rochester, N. Y.
Farmers' Nursery Co., Troy, Ohio.
First National Nurseries, The, Rochester, N. Y.
Fruit Growers' Nurseries, Newark, N. Y.
Hawks Nursery Co., The, Rochester, N. Y.
Herrick Seed Co., Rochester, N. Y.
Hooker, Wyman & Co., Rochester, N. Y.

Hubbard Company, The T. S., Fredonia, N. Y.
Huntsville Wholesale Nursery Co., Huntsville, Ala.
Jewell Nursery Co., The, Lake City, Minn.
Knight & Bostwick, Newark, N. Y.
McGlennon & Kirby, Rochester, N. Y.
McKay Nursery Co., The, Pardeeville, Wis.
Moore & Son, Jas. P., Greenfield, Ind.
Moore & Co., Wm. C., Newark, N. Y.
Pennsylvania Nursery Co., Girard, Penn.
Perry Nursery Co., The, Rochester, N. Y.
Ringler Rose Co., Chicago, Ill.
Saddler Brothers, Bloomington, Ill.
Simpson & Sons, Vincennes, Ind.
Standard Nursery Co., The, Rochester, N. Y.
Stark Bros. Nurseries and Orchards Co., Louisiana, Mo.
Stuart & Co., C. W., Newark, N. Y.
Swain-Nelson & Co., Chicago, Ill.
Taylor & Co., H. S., Rochester, N. Y.
Willett & Wheelock, North Collins, N. Y.

REPORT OF SUPERINTENDENT OF FARMERS' INSTITUTES.

President J. L. Snyder:

Sir: The attendance and interest at the Farmers' Institutes held during the past year have never been equalled in Michigan. In fact, at a large number of places the largest halls would not accommodate the people who wished to attend and many were obliged to return home for lack of even standing room inside the door. An energetic county secretary and a business-like, hustling local manager will generally be able to secure a good attendance. As a rule, the most interest has been shown in the counties where the greatest advancement is being shown by the farmers, as such men feel they still have much to learn and they realize that one of the best ways of still further improving their methods is by getting together and comparing notes with other farmers. The few who, instead of attending the institutes, hang around the street corners or frequent the saloon, asserting, "Them fellers can't teach me nothin' about farmin'," are always the least progressive farmers in the section. They are generally owners of scrub live stock, they are soil robbers and grow the poorest crops of any farmer in the vicinity.

During the year 412 institutes have been held. This includes 80 county meetings and 332 one-day institutes. Arenac county in the lower peninsula and Houghton and Keweenaw in the upper peninsula are the only ones in Michigan that have not had at least one institute, while at the other end of the list stands Lenawee county with 18 one-day institutes in addition to the county institute.

COUNTY INSTITUTES.

The attendance at the 79 county institutes has been 58,914, or an average at each of the 377 sessions of 156, besides 5,193 at the State

Round-up institute with an average attendance of 519 at each of the ten sessions.

The county institutes lasted two days, except as follows: In Mason county there was a four days' farmers' school under the direction of the county secretary, Mr. C. A. Rinehart, who is also county commissioner of schools; in Manistee and Grand Traverse counties the meetings lasted three days, the last day being joint farmers' and teachers' institutes; and in the upper peninsula it was thought best to only hold one-day institutes.

For these meetings two speakers upon farming topics, and one lady were furnished. At most of them, there was also an additional speaker to take the third hour in the afternoon and to give an address in the evening. Good Roads, cement and education were among the topics considered by this speaker at the afternoon sessions.

ONE-DAY INSTITUTES.

At the 340 one-day institutes, the total attendance was 80,054 or an average of 100 at each of the 802 sessions.

The interest and attendance shown at the one-day institutes was more than satisfactory. At a large number of places the people could not be accommodated with seats and often standing room was at a premium. The only meetings which have not been satisfactory have been those where the county secretaries have not given personal attention to them and where the local managers have not taken pains to see that the meetings are properly advertised.

It should be stated, however, that in a great majority of the counties the secretaries have not only visited the different points where institutes are to be held, and aided the local managers in making the preliminary arrangements, but they have in many cases spent from one to two weeks in attendance at the institutes. The presidents of the county institute societies have also devoted much time both to arranging the institutes and attending the meetings.

WOMEN'S CONGRESSES.

About the same number of counties have had separate sessions for the women as in previous years, and where suitable arrangements have been made for them, and they have been properly advertised, they have been well attended and have been very helpful.

In most places they have been held in the afternoon but in a few counties a session has been held the second evening and the exercises have been in charge of the ladies.

The plan of having a Women's Congress during one or both afternoons of the institute seems to have much merit. While there might be topics that would be instructive and interesting to them on the program in the general session, it would seem that a separate session would be more helpful, as it tends to bring the women closer together than would be possible if joint sessions only were held. Then, too it brings together the women from the farms and those from the towns and they not only become acquainted personally but they learn from each other and thus obtain a broader view of life.

Not the least of the advantages of the separate sessions is that the

women feel more free to take part in the discussions, and while at the general session they might not even ask a question, but the free discussion which is so helpful is common at well conducted women's sessions.

In some counties they have arranged for a Women's Congress with two sessions, either forenoon and afternoon, or on two afternoons; and in still others, three or four sessions are held during the year. By holding them in different parts of the county it not only enables all of the women to attend at least one of the Congresses, but it affords an opportunity for the different localities to come into closer touch for the common good.

In the counties where the *ad interim* Women's Congresses are being held, they are conducted more along the lines of mothers' meetings, community clubs or housewives' leagues. In many parts of the state the women are manifesting more and more an interest in just such meetings and the plan is to supply this demand, so far as possible, and to furnish an outline for each Congress to follow. This part of the work will be more in the nature of home study clubs, and will be supplemented with suggestions and helps from this department and the loan collections of books and pictures furnished without charge by the State Library.

EXHIBITS AT INSTITUTES.

Among the interesting features at a large number of the institutes were the exhibits of corn, grains, potatoes and other vegetables, bread, butter, plain sewing, drawings, etc. At several places exhibits of work by school children were made.

A large proportion of the exhibits were by boys and girls and at some of the meetings the exhibits were made under the auspices of the Boys' Corn Club, which also held separate sessions at which a regular program was carried out. At other institutes the exhibits were secured either by the secretary, or by a committee on exhibits, appointed to take charge of the work.

Premiums of considerable value were generally arranged for, either from the treasury of the institute society or in the way of cash, farm implements, merchandise, etc., offered by individuals.

Such exhibits should be encouraged, as they not only add to the interest and attendance at the institutes but they are instructive and inspiring and serve to induce a greater interest in farming and farm life, both on the part of those who make the exhibits, and those who view them.

In arranging the premiums, those for boys and girls should have particular attention, and an endeavor should be made to have them of an educational nature, such as trips or short courses at the Agricultural College, trips to the State Fair, books on agriculture or home economics, etc.

The larger prizes should only be offered for the growing of a half acre or more of corn, potatoes or other crops, and the contestants should not only be required to keep a careful record of the growing of the crop, its yield, etc., as well as make an exhibit of the product, but the reports of those who receive the prizes should be read at the county institute.

There should be similar requirements in the case of girls who compete for prizes upon bread, butter, sewing, laundering, etc.

ACKNOWLEDGMENTS.

The institute work carried on during the year has only been possible through the co-operation of other state institutions.

As usual, the normal schools have furnished a number of speakers for the county institutes as well as for the one-day meetings. Much good has also been secured by the co-operation of the school commissioners in a large number of counties who have furnished a speaker upon educational topics for two sessions of each one-day institute held in the county. The State Highway Department has as usual co-operated by furnishing speakers, as has also the State Dairy and Food Department.

Several members of the Agricultural College faculty, as well as of the Experiment Station and Extension departments, have also attended a large number of institutes. Arrangements have also been made with the State Library Commission, State Board of Health, and the State Pioneer and Historical Society, by which representatives of those organizations should appear on the program of the institutes.

One of the first rules in the selection of speakers and topics for farmers' institutes is that nothing which savors of advertising shall be allowed upon the institute programs, hence great care was exercised in making the selections. A number of corporations have organized extension departments in charge of experts whose duty it is to bring before the people the proper methods of using the articles manufactured or sold by the respective firms, with the idea that better results would be secured, and hence being satisfied, it would lead to larger sales by the company.

Among these firms are, the Universal Portland Cement Company and the German Kali Works, both with offices in Chicago. Arrangements were made with each of them to place one of their lecturers upon the programs of a number of the institutes, with the understanding that they were to only discuss the proper methods of using cement on the one hand, and fertilizers on the other, and in no way urge the merits of their particular brands.

This was closely adhered to by the speakers, and much good should result from their efforts.

These men were furnished without any expense, whatever, and as the lecturers from the different state institutions have merely received their traveling expenses, the co-operation in this way has materially increased the number of institutes it has been possible to hold.

The U. S. Department of Agriculture not only co-operated by allowing the county and district agents to take an active and helpful part in the county institutes, but furnished two speakers, Professor Clinton and Miss Bailey, for the State Round-up institute without expense.

CO-OPERATION WITH COUNTY AND DISTRICT AGENTS.

During the year agricultural agents have been appointed in several counties through a joint arrangement between the Michigan Agricultural College, the U. S. Department of Agriculture and the County Farm Bureaus. Dr. Eben Mumford was chosen as State Leader and several district supervisors were selected.

Some of the appointments were not made until after the arrangements had been completed for holding the institutes, and the fact that most of those who had been appointed up to that time were called to Washington to a conference for three weeks in January, the time when most of the institutes are held, prevented any very complete co-operation. Hon. Jason Woodman, agent for Kalamazoo county, and J. H. Skinner, holding a similar position in Kent county, arranged to attend all of the institutes in their respective counties, and also effected an exchange for three institutes.

Mr. H. J. Smith attended the institutes in Montmorency, Alpena and Presque Isle counties, and Messrs. M. J. Thompson and Chas. P. Reed, supervisors for groups of twelve counties, including respectively most of those in the 9th and 11th congressional districts, were able to attend at least one institute in each county in their respective districts. The work of Mr. Thompson was especially helpful as he attended 25 institutes, besides aiding in making the arrangements in several of the counties.

SPEAKERS AT THE ROUND-UP.

The list of speakers at the State Round-up Institute was an unusually strong one. It included Dean Eugene Davenport of Illinois, upon, "The Need of Improved Live Stock," and "Recent Progress in Agriculture;" Dean R. H. Price, of Ohio, upon "Farm Credits," and "The Present Trend of Agricultural Education;" Prof. C. G. Williams, of Ohio, on "The Use of Farm Manures and Commercial Fertilizers," and "Corn Improvement by Selection and Breeding;" Prof. O. F. Hunziker, of Indiana, on "The Care of Market Milk," and "Economical Rations for Dairy Cows;" Prof. L. A. Clinton, of the Farm Management Bureau, U. S. Department of Agriculture, who spoke upon "Potato Culture," and "Farm Management Work of the Department of Agriculture;" and Miss Ilena Bailey, also of the same Bureau, who spoke to the ladies upon "How can we Solve the Problems of the Farm Home," and at the general session upon "The Farm Woman's Share in Improved Agriculture."

Of Michigan speakers, Prof. J. A. Jeffery perhaps did most to make the meeting a success, as he gave four lectures upon land drainage and the use of plows and other farm tools. The list of those who took part either in the program, or in providing the exhibits and demonstrations is a long one and need not be repeated here. All of them aided materially in bringing off a successful meeting.

The music was provided entirely by individuals or organizations at the college. The arrangements were under the charge of Miss Louise Freyhofer, the college Director of Music. The college band and Girls' Glee Club each furnished the music for one evening and received many encores.

RAILROAD TRAINS.

In former years from fifteen to thirty days have been devoted to railroad institute trains, but during the past fiscal year only two days have been spent in this way and these were the first two days in the year which were spent in finishing up a trip upon the Ann Arbor railroad.

From the fact that trips had been made over practically all of the roads in the state within two years, no attempt was made to arrange

for such trains except upon the Grand Trunk, for which a ten-day trip was planned but it was finally given up.

Several roads whose requests for trains were declined last year have asked for trains during the coming season and it is proposed to spend at least three weeks in this way.

AN APPRECIATION.

While the preliminary work of planning for the institutes, such as fixing the dates, securing speakers, making out programs, etc., is done in this office, the real work of making the arrangements for the institutes devolves upon the county secretaries and local management, as unless they see that each of the details has attention, and the meetings are thoroughly advertised, the institutes are likely to be failures so far as interest and attendance are concerned, however carefully the work in this office has been done. For these reasons the excellent work done by nearly all of the county secretaries and most of the institute officers is hereby gratefully acknowledged.

Splendid service was also rendered by the institute lecturers. Several of them have been on the force for a dozen years or more and when they are present at an institute, favorable reports are generally received. The reports received from the county institute officers regarding the ability of the lecturers have been, without exception, very complimentary, and the efforts they have put forth and the loyalty shown by them, merits the highest commendation.

The work in this office has been under the direction and oversight of my assistant, Miss Vesta C. Haney, who has been in charge of the office in the absence of the writer, and has materially assisted in the preparation of this report. The supervision of the women's meetings and community clubs, has also been in her charge and she has offered many helpful suggestions that have had much to do in securing a successful institute season.

Respectfully submitted,

L. R. TAFT,

Supt. Michigan Farmers' Institutes.

East Lansing, Mich., June 30, 1913.

TWENTY-SIXTH ANNUAL REPORT

OF THE

EXPERIMENT STATION

OF THE

Michigan Agricultural College

UNDER THE HATCH AND ADAMS ACTS

FOR THE

YEAR ENDING JUNE 30, 1913

For members and organization of the State Board of Agriculture in charge of the Station and list of officers, see page 13 of this volume

REPORT OF SECRETARY AND TREASURER.

The following shows the receipts and disbursements of the Experiment Station for the year ending June 30, 1913.

	Dr.	Cr.
July 1, 1912—To balance overdrawn	....	$1,708 78
July 20, 1912.....received from U. S. Treasury	$2,500 00	
Sept. 13, 1912.....received from U. S. Treasury	5,000 00	
Oct. 12, 1912.....received from U. S. Treasury	7,500 00	
Jan. 18, 1913.....received from U. S. Treasury	7,500 00	
April 16, 1913.....received from U. S. Treasury	7,500 00	
June 30, 1913.....license fees, 286 brands com'l fertilizers	5,720 00	
farm and miscellaneous receipts	362 80	
from State appropriation, South Haven Experiment Station	2,000 00	
from State appropriation, U. P. Experiment Station	15,000 00	
South Haven Experiment Station, receipts	199 70	
U. P. Experiment Station receipts	3,252 15	
By disbursements as per vouchers filed in the office of the State Auditor General	....	52,633 02
Balance on hand	....	2,192 85
Total	$56,534 65	$56,534 65

Two hundred fifty thousand regular bulletins Nos. 268, 269, 270, 271; forty-five thousand special bulletins Nos. 59, 60, 61; fifteen thousand technical bulletins Nos. 12, 13, 14, 15, 16; thirty thousand circular bulletins Nos. 18, 19, 20; two thousand press bulletins Nos. 28, 29, 30 have been issued by the Experiment Station during the fiscal year.

DISBURSEMENTS ON ACCOUNT OF U. S. APPROPRIATIONS.

	Hatch fund.	Adams fund.	Total.
Salaries:			
Director and other administrative officers	$2,078 90	$291 50	
Scientific staff	3,091 00	1,125 00	
Assistants to scientific staff	3,384 65	9,452 56	
Labor:			
Annual and monthly employees	1,572 31	357 58	
Weekly, daily and hourly as needed	1,229 78	1,104 91	
Publications:			
For envelopes for bulletins and reports	13 50	....	
Other expenses	273 14	....	
Postage and stationery:			
Postage	210 02	2 03	
Stationery	119 71	13 20	
Telegraph and telephone	11 50		
Freight and express	4 75	3 87	
Heat, light, water and power	115 32	....	
Chemicals and laboratory supplies:			
Chemicals	217 57	280 19	
Other supplies	295 95	416 19	
Seeds, plants and sundry supplies:			
Agricultural	14 72	....	
Horticultural	217 02	....	
Botanical	57 40	55 18	
Entomological	11 58	17 59	
Bacteriological	68 85	57 15	
Chemical	49 22	8 02	
Soils	....	10 27	
Director's office	48 42	....	

DISBURSEMENTS ON ACCOUNT OF U. S. APPROPRIATIONS —*Concluded.*

	Hatch fund.	Adams fund.	Total.
Scientific apparatus and specimens:			
Five soil thermometers		$29 92	
One rotary pump with motor		150 00	
One induction coil		18 00	
One resistance box		24 00	
One Kohlrausch Bridge		70 00	
One temperature indicator		108 00	
One A. C. galvanometer		100 00	
One generator		93 60	
One resistance box		97 20	
One 179.92 Grm platinum		305 86	
On rotary pump	$150 00	....	
On wardean case	135 34	....	
On wardean case	117 07	....	
Other purchases	69 00	386 50	
Fertilizers	20 00	....	
Feeding stuffs		38 00	
Library:			
One copy physical papers		7 50	
One copy Enzymes		1 50	
One copy Phys. of Reproduction		5 66	
One copy Enzymes		3 00	
One set Zeitschr. f. Physik Chemie	35 70	....	
One set Selects fungorum	40 50	....	
One set Arbeiten sus. d. k. biolog	40 43	....	
One Chemisches Centralblatt	17 00	....	
Binding 56 volumes ½ morocco	50 40	....	
One set Journal of Physical Chem. Vols. 1-13	75 00	....	
One copy Biochemische Zeitschrift	47 04	....	
One set Cent. f. Bakteriologie Orig. Abt	18 00	....	
One set Cent. f. Bakteriologie Ref	21 60	....	
One set Cent. f. Bakteriologie 2 abt	11 40	....	
One copy Chemishes Centralblatt	20 00	....	
One set Geneva Insectorium	18 56	....	
Six vol. Icones Fungorum Lucasme Cogrutorum	176 10	....	
Miscellaneous	467 80	20 77	
Tools, machinery and appliances:			
New purchases	46 50	17 95	
Repairs	15 20	....	
Furniture and fixtures:			
Two sections Gunn's bookcase	....	6 00	
One No. 352 cabinet	....	4 00	
One ladder	4 00	....	
One cabinet	16 40	....	
One upright unit No. 331	25 65	.....	
Other purchases	5 56	9 27	
Live stock:			
Small experimental animals		33 00	
Traveling expenses:			
In supervision of station work	51 01		
In connection with investigations under the Adams Act	....	136 81	
For other purposes connected with station work	118 12	....	
Contingent expenses	20 00	....	
Buildings and land	36 01	108 16	

DISBURSEMENTS OF EXPERIMENT STATION MONEYS—OTHER THAN RECEIVED FROM U. S. TREASURER.

Salaries	$5,219 85	
Labor	7,265 83	
Publications	15 07	
Postage and stationery	682 28	
Freight and express	336 68	
Heat, light, water and power	17 38	
Chemicals and laboratory supplies	215 35	
Seeds, plants and sundry supplies	1,451 98	
Fertilizers	22 50	
Feeding stuffs	120 06	
Library	16 17	
Tools, machinery and appliances	416 88	
Furniture and fixtures	258 01	
Scientific apparatus and specimens	256 40	
Live stock	2,409 47	
Traveling expenses	1,009 31	
Contingent expenses	7 00	
Buildings and land	2,882 80	
Total		$22,633 02

REPORT OF THE DIRECTOR OF THE EXPERIMENT STATION.

To President J. L. Snyder:

The work of the Michigan Agricultural College Experiment Station is quite fully outlined in the individual reports of the heads of the divisions which follow. As was stated in last year's report further extension of station work is dependent entirely on supplementary state aid for the federal appropriations. During the year the $15,000 Hatch fund was divided approximately as follows, viz: for salaries $8,554.55 and operating expenses $6,445.45, while the $15,000 Adams fund was divided as follows, viz: Salaries $10,869.06 and operating expenses $4,130.94. Of the state funds $3,338.45 was apportioned for salaries and $3,417.52 for operation. These sums do not include the appropriations for the sub-stations which were as follows, viz: South Haven Fruit Sub-Station $2,258.44 and the Upper Peninsula Station at Chatham $13,618.61.

It is evident therefore from the above statement that further additions cannot be made to the present staff of investigators without supplementary state aid. There is perhaps no state in the country which presents a greater variety of problems because of varied production due to great variation in the character of our soils and the peculiar and favorable conditions of environment due to geographical location. There are many lines of production needing the support of the station at present which we are unable to meet.

One change only, has taken place during the year so far as the personnel of the Station Council is concerned. Professor J. A. Jeffery, Soil Physicist of the Experiment Station, resigned about the close of the year to accept the position of Commissioner of Agriculture and Immigration for the Duluth, South Shore and Atlantic Railroad. While the efficient services of Professor Jeffery will be missed, still the new position presents a large field of endeavor and it is hoped that his work in addition to the college extension work in the Upper Peninsula will

prove to be a stimulus which will accelerate the development of the agriculture of that region. Changes on the advisory staff have been noted by the various departments. The Poultry and Farm Mechanics departments have been officially connected with the Station during the year.

At the Upper Peninsula Station at Chatham, Michigan, the work of land clearing and seeding have continued. Last year about one hundred acres of hardwood stump land was burned over and seeded. The stand of mixed clovers and legumes this year is almost perfect. In addition to the regular stock equipment three cars of yearling wethers have been shipped to Chatham from Chicago for grazing and browsing purposes.

During the year pedigreed animals of the following breeds of live stock were sent to equip the Chatham Station, viz: Holstein cattle, Rambouillet and Hampshire sheep, Duroc Jersey swine and Barred Plymouth Rock and White Leghorn chickens.

During the present season construction work is in progress on the dairy barn floor and stall fixtures, root cellar, silo, ice house and piggery. The supervision and much of the actual work is being done by the Farm Mechanics staff of the college.

Since the opening up of spring nearly three and one-half miles of woven wire fence has been built with cedar posts a rod apart and wire forty-two inches high with barbed wire on top. This fencing is nearly all for purpose of enclosure along public roadways.

A report of the South Haven Sub-station is given separately hereafter.

The following is a report of the work in progress in the Department of Animal Husbandry:

"During the winter of 1911-12 records were kept of the cost of wintering the beef herd. All of the females were bred to calve in the spring of 1912 and were wintered as economically as possible and turned on pasture early, the calves being allowed to run with them. The object of this work was to determine the cost of raising a beef calf to one year of age.

"Starting in January, 1912, an experiment has been conducted with young calves to determine the advisability of using preservatives to keep milk sweet for calf rearing. Three lots of calves are being fed, Lot I receiving sweet skim milk direct from the separator, Lot II milk kept sweet by the use of formaldehyde and Lot III milk which has been allowed to sour.

During the latter part of May two Tamworth sows were bred to a Poland China boar, two to a Duroc Jersey boar and two to a Berkshire boar. The pigs will all be raised to a marketable age under identical conditions to determine the best cross for profitable pork production."

The following is a list of the publications of the year, viz:

Regular bulletins—

268—Wheat Improvement, by F. A. Spragg.

269—Fertilizer Analyses, by A. J. Patten, Arao Itano, Wm. C. Marti.

270—Seed Analyses, by E. A. Bessey.

271—Alfalfa Growing in Michigan, by V. M. Shoesmith.

Circular—

18—Cover crops for Michigan Orchards and Vineyards, by H. J. Eustace.

19—Cucumbers as a Cash Crop, by Walter Postiff.

20—Starting a Lawn, by C. P. Halligan.

Technical—

12—Neutral Ammonium Citrate Solution, by A. J. Patten, C. S. Robinson.

13—What is the Antigen Responsible for the Antibodies in Dorset-niles Serum? by Ward Giltner.

14—Infectious Abortion and Sterility in Cattle, by Ward Giltner.

15—the Influence of Certain Acid-Destroying Yeasts upon Lactic Bacteria, by Zae Northrup.

16—The Bacterial Activity in Soil as a Function of Grain-Size and Moisture Content, by Otto Rahn.

17—An Investigation of Soil Temperature and some of the most Important Factors Influencing it, by Geo. J. Bouyoucos.

Press—

28—Grounding Lightning Rods, by A. R. Sawyer.

Special—

59—Small Fruit Culture, by Frank A. Wilken.

60—Celery Culture in Michigan, by C. P. Halligan.

61—Spray and Practice Outline for Fruit Growers, by R. H. Pettit, H. J. Eustace.

R. S. SHAW,
Director Experiment Station.

East Lansing, Mich., June 30, 1913.

REPORT OF THE BACTERIOLOGIST.

Director R. S. Shaw:

Dear Sir—The Experiment Station work of the Bacteriological Laboratory has continued throughout the past year along the same general lines that were in operation at the close of the preceding year. We have made an extra effort to place the results of our investigations and endeavors in such form as to be of immediate and tangible service to the farmers of the state without in any way interfering with the quality of pure research.

Concerning the soil investigations, I can with a certain degree of safety predict the dawn of a new era as a consequence of the patient and painstaking work of Dr. van Suchtelen with the loyal support and admirable technic of Mr. Itano. For successful research in soil bacteriology, it would seem to me essential that there be prepared or isolated the substance essential for the life and growth of the soil microorganisms, viz: the soil solution. I have carefully followed Dr. van Suchtelen's work and am satisfied that his viewpoint is correct and that his results are based on correct ecological principles. It is also clear to me that with this work as a basis we are now in a position to accomplish something fundamental biologically whether in microbiology or in plant physiology. A general outline of Dr. van Suchtelen's work is quoted directly:

INTRODUCTION.

"After a careful study of the literature of soil bacteriology, I may say that it is my conviction that most of the present investigations in

soil-bacteriology have little or no practical value for applied agriculture. These investigations may be classified as follows:

I. Numerical determination of bacteria in soil.
II. Determination of species in soil.
III. Transformation experiments after Remy, Löhnis, etc.

These experiments, however valuable they may be theoretically, have practically no value for a practical agriculture, because they fail to consider the fact that the bacterial content of the soil is determined almost entirely by the physical and chemical conditions of the soil and that the microflora in the soil exists in the soil solution. If it is our final aim to aid agriculture, then soil bacteriology can be successfully developed only by a thorough study of the soil solution and by influencing this solution intelligently so as to make the work of the soil bacteria more profitable.

In physiology we recognize the influence of environment on the single cell. Not only if we take the high water content of the living substance into consideration, but also if we consider metabolism as the manifestation of the phenomena of life, the importance of water in the life process is made clear. Without water there is no life. By adding to or diminishing the water of the living substance within certain limits, we increase, diminish, or limit the intensity of life processes. The environment of bacteria is water, and soil bacteria form no exception. There, where there is little or no water at their disposal, the metabolic processes are reduced to a minimum. Spores, cysts, and other defensive organs are the results of the dryness of the medium. In a former publication[1], the author has tried to make a numerical comparison between the water content of the soil and the activity of the soil bacteria. As an indicator the carbon dioxide production in soils was chosen, a metabolic product that is formed in nearly all life processes in comparatively large quantities, and in easily detected form. Without going into detail with these experiments, I will say that if the soil contained only 4.4% of water, the soil bacteria would be unable to attack the easily broken down dextrose which was added to the soil. I take this as an example illustrating the overwhelming importance of the water content for the biochemical action in soils.

From the foregoing it is clear that water is the medium of soil bacteria. Although one cannot make in practice a sharp distinction between the quantity and the nature of the water, I should like to cite the experiments of Beyerinck[2] as evidence of the influence of the nature of the water, on the microörganisms. His experiments deal chiefly with unicellular organisms, and let us say here that the "ecological method" proved to be of especial value, in the case of the lower organisms, because they are unicellular and expose in comparison with their content such an enormous surface, on which the medium can act.

In his classical investigations Beyerinck showed the dominating influence of the nature of the water environment on the behavior of the microörganisms. How uniform was the material with which he started must be noted, for it was in many cases the mud of the canal

[1] F. Hesselink van Suchtelen, Centr. bl. f. Bakt. II Abt. Bd. 28, S 15.
[2] F. Stockhausen, Oekologie Anhaufungen nach Beyerinck.

in Delft. By influencing intelligently the life conditions of bacteria, such as oxygen and food supply, temperature and many other factors, he was able to predict and to obtain with mathematical surety the predominating flora.

In such experiments as this on the nature of the water, Soil Bacteriological Science finds its greatest promise.

If we ask ourselves: What is the ultimate aim of the applied science of Soil Bacteriology?, the answer must be: The aim of Soil Bacteriology (aside from the purely scientific interest) is to put the action of the soil bacteria in the service of agriculture, to suppress the detrimental species and their action, and to encourage the beneficial bacteria like those which accumulate nitrogen, and such as make available those compounds of the soil which are in a state not available for plant nourishment.

To accomplish this, or, in other words, to influence the microörganisms in the soil intelligently, presupposes the necessary knowledge of the environment of the bacteria, of those factors which are at our command, that can be varied as we desire, such as oxygen supply, water, reaction, etc.

Let us now consider the soil and let us treat it from the point of view of a medium for the microflora. Soil is composed of three states of material, solid material, water and air; and these three states have a marked influence on each other. The soil bacteria are living in the soil water, but this soil water is influenced very markedly by the solid material and by the air. It is this that makes the soil a difficult medium to investigate. I might say here that I know of no medium that is so variable and complex as soil. If we consider milk in this respect, the air, and the solid substances, play only a very small rôle. It can also be said that the milk of different cows does not differ materially as a medium for the bacteria. On the other hand, we know how large are the differences in soils which must necessarily influence their microflora.

We encounter still another difficulty if we remember the fact that our medium (the soil) is very difficult to sterilize. Only by the action of powerful agents are we able to sterilize the soil, in fact, the changes, which are necessarily brought about by this sterilization process, are so marked that we doubt even if we may call this sterilized medium, soil.

This means that in the case of soils we are practically deprived of the opportunity of recording the action of single species of microörganisms. Further, soil is especially characterized by enormous surfaces. To give an idea how great the soil surface is, I should like to cite the work of Alfred Mitscherlich[3] who came to the conclusion that the outer surface of one gram of quartz sand was 1.38 square meters and that of one gram of clay was 966.7 square meters. These enormous surfaces give us an idea of how closely the soil water can be in contact with the solid soil substance.

In regard to the permeability, I regret to say that we have but very little trustworthy data. The reason for this is evident, namely, that the many values obtained with air-dried soil do not permit any conclusions for field conditions. We may say, however, that the permeability of the different soils is extremely variable.

From the foregoing, it is clear that, even in fine tertiary quartz sand,

[3]A. Mitscherich, Bodenkunde fur Land und Forstwirte, 1905, pp. 19-73.

which has so great a surface, there is great possibility for action between the soil water and the absorbed substances on the soil grains.

To the question, What is the nature of these reactions between the soil water and the soil particles?, the answer cannot be very satisfactory. Permit me, however, to draw your attention to some experiments which give us the right to suppose that these reactions are different from the reactions that occur in a beaker or a test tube.

Aside from the phenomenon of selective absorption which we know takes place in soils, we have at our command a number of experiments performed by the most distinguished chemists showing that the amount and kind of surface possesses marked influence on the reactions. I cite here the work of van't Hoff who concludes that both the nature and the amount of surface exposed have an influence. The inversion of sugar is affected by the nature of the walls of the containing vessel, and its reduction by Fehling's solution is affected by the walls and the amount of cuprous oxide formed in the reaction. An admirable exposition of this phase of the subject may be found in "The Mineral Constituents of the Soil Solution," by F. K. Cameron and James M. Bell.[4] In the case of soils where we have so large a surface and such thin films, absorption, surface tension, and other not-well-defined molecular forces may and will play their rôle.

It follows then that the addition of an excessive amount of water to soils (drainage) changes the conditions, i.e. salts that were not in solution in the soil solution will be found to be dissolved in the drainage water, and we have therefore, the right to suppose that the drainage water is different, in a qualitative and quantitative respect, from the film water which surrounds the soil particles. It is, therefore, impossible to make any conclusion, from the analysis of drainage water on the soil solution as it exists in the soil, because the dissolving process is probably not proportional to the amount of water added.

On account of the importance of the environment of the soil bacteria, a knowledge of the solution as it exists in the soil becomes most urgent. And here we may add that this subject does not only concern the lower forms of life, but in the case of higher plants also, the study of the soil solution promises fruitful results.

So I have directed my study towards this theme and have been seeking a method which would furnish me some soil solution. Here, again, we meet with some difficulties which I should like to mention briefly.

It is absolutely impossible to obtain a comparison between the obtained soil solution and the total soil solution, because every method for securing the soil solution can give only a percentage of the total solution, as the last traces of soil water are held back tenaciously by great forces.

The method finally adopted consists of the displacement of the soil solution by means of paraffin oil. There is something depressing in the impossibility of being able to verify our obtained results with the reality.

With the kind assistance of Mr. Itano, some experiments have been made. Sulphuric acid of known strength was added to carefully washed, dry quartz sand. After this, paraffin oil was poured on the sand and by means of a suction pump the acid was regained. The

[4] Bull. No. 30, Bureau of Soil, U. S. Dept. of Agriculture.

titration showed that the so-obtained acid did not differ from the acid which was used in the experiment. I am perfectly aware of the fact that this experiment has practically little bearing on soil conditions. The fact, however, that our regained solution had the same composition as the solution originally employed does not mean that our method is not permissible.

There must be considered, then, the nature of the medium with which we displace the soil solution. We may congratulate ourselves on the choice of paraffin oil as a medium. With the most refined instruments that were at our service, we were unable to detect any change in the solution when it was brought into intimate contact with the paraffin oil. We found then, that the inactive paraffin oil did not change the electrical conductivity of the soil solution, while the chemical analysis also showed that there was no change brought about by the action of the paraffin.

The third method which we employed was the measuring of the surface tension. We might expect that when only slight traces of the paraffin oil were dissolved in the soil solution, this would have its marked effect on the surface tension of this liquid. However, we were unable to detect any change in the surface tension of the liquid after it had stood for a long time covered with the paraffin oil. So far, the results obtained have demonstrated the permissibility of the use of the method employed.

In regard to the amount of the soil solution that can be extracted by the application of our method, I must say in advance that even slight modifications even of the apparent details of our process caused large variations in the amount of water obtained.

If we record only the values obtained, by the use of those conditions which we knew to be most satisfactory, then we must record the amount of solution obtained as a percentage of the total water capacity.

But, at present, there exists in few fields of soil physics such conflicting interpretations as exist in regard to the meaning of the term "water capacity." In the different text and laboratory books, we find the most diverse definitions and the most conflicting methods for the determination of this total water capacity. Because we suspected that this value would vary quite markedly with the application of the differently devised methods, we undertook some experiments which proved that our supposition was correct. The total water capacities of the same soil as determined by the different methods varied over thirty per cent. From the soils containing the maximum water capacity we were able to extract over seventy per cent of the total water. As an example, I will cite in this connection the data of an average extraction.

From eight kilograms of soil (clay) which contained 14.3% water (figured on the basis of dry soil) was obtained 330 cc. of soil solution. It is evident that such results can not be obtained by the use of a simple suction pump where the maximum difference of pressure is necessarily less than one atmosphere.

However, we have secured larger differences in pressure by means of a hydraulic press.

We now have the soil solution and will analyze it. There are two ways in which we may investigate such a solution which require a short explanation.

I. The chemical analysis.
II. The physiological analysis.

A chemical analysis seeks through its results a determination of soil fertility. However, one can not claim that this method has been especially successful. The only thing which we can say with surety about its results is that if a certain nutritive element is found to be absolutely not present in the soil, then it is lacking for the nutrition of the plant. The difficult problem concerning the relation between chemical analysis and availability still awaits solution.

The physiological analysis draws its conclusions from the vegetation itself. In other words, it is an attempt to put direct observation in the place of theoretical deduction. Since no definite results from the analysis of the soil solution have been so far obtained, and since one must recognize that the latter has no scientific value as a determination of soil fertility, the author has applied not only chemical analysis to the solution but in connection with this also a physico-chemical analysis.

We may suppose from analogy that the physico-chemical analysis of such a liquid may be of exceptional value. However, I must emphasize that in spite of all the various determinations I do not feel myself called upon to draw any definite conclusions from these analyses with reference to the exceedingly complex question of soil fertility. So far as chemical analysis is concerned, we must keep before ourselves the all important fact, "corpora non agunt nisi soluta," in other words, that only which is present in the soil solution can be taken up as a nutritive substance, but not everything present need be taken up.

There still remain a few things which I should like to say. I will state the facts that were revealed by the application of our method. Complete results will appear in a publication of the near future.

This is not the place to discuss the details of the different analyses.

(1) In many cases there was found in the soil solution a slime. This must be regarded as the first experimental proof of the presence of this substance in soil, and it is not impossible that much of the irregular behavior of the life in soil could be explained to some extent with a knowledge of this slime. If I may be permitted, I should like to call your attention to the possibility of this substance having an effect on desiccation, diffusion, and other processes.

(2) The specific gravity of the soil solution which influences the movement of the soil water was found to be higher than that of water.

(3) As to the viscosity of the soil solution which governs to a certain extent the rate of adjustment of soil water in the soil, we can say that it is relatively high.

(4) The surface tension, a property of liquids which is associated with adsorption and has an influence on the degree of capillarity, was found to be distinctly low in the case of the soil solution.

(5) In reference to the osmotic pressure of the soil solution, which on one hand is the indicator of the state of solubility, and has a bearing on the adjustment of the water in the soil, and on the other hand markedly influences the life in the soil, we can say that this pressure is low, a result which was to be expected from the comparatively high resistance of the liquid.

(6) Another thing noticed is the acid and basic binding capacity. This was found by the electrotitrimetric method. In general we may

say that the neutrality was obtained by adding very small quantities of a hundredth normal alkali or acid.

(7) In regard to the chemical analysis you will not be surprised to hear that all nutritive substances could be found in our soil solution to a certain degree. An astonishing fact, however, is the relatively large quantity of nitrates in some samples. With reference to the value of the chemical analysis of the soil solution, I refer to that which I have already said.

Our work can by no means be looked upon as complete, but I dare say that the results are promising, and that I feel happy to be able to present to the reader the preliminary results which have been obtained by the application of the methods of Mr. Itano and myself.

LITERATURE.

1. F. Hesselink van Suchtelen, Centr. bl. f. Bakt. II Abt. Bd. 28, S 45.
2. F. Stockhausen, Okologie Anhaüfungen nach Beyerinck.
3. A. Mitscherlich, Bodenkunde für Land und Forstwirte. 1905. p. 49-73.
4. Bull. No. 30, Bureau of Soil, U. S. Dep't. of Agriculture.

Mr. C. W. Brown has continued his investigations on the keeping qualities of butter and has nearly ready for publication the data relative to another phase of this problem. It is expected that this immediate problem will be completed during the ensuing year during which time it is hoped that Mr. Brown will devote considerable time to problems concerning the nodule-forming bacteria. Plans are being made to furnish assistance for this work.

Dr. E. T. Hallman has assumed the duties that I was formerly concerned with. He has assisted the Live Stock Sanitary Commission in a manner that has gratified all parties concerned. He has also devoted considerable time to a study of some of the problems connected with hog cholera; but his most important work has had to do with infectious abortion in cattle. Immunization experiments and the possibility of using the complement fixation and agglutination tests have formed the basis of the work. We feel hopeful that these researches will eventually be fruitful. In the meantime, we are adopting a policy of caution and watchfulness. Dr. Hallman submits the following notes which should be recorded here:

My work with infectious abortion of cattle is a continuation of the work begun by Dr. Giltner. We are pursuing two lines of investigation: first, a study of the means at our command for the diagnosis of the disease, and second, the search for some practical, effective method of controlling the disease.

The first line of investigation is an exceedingly important one in our estimation. If abortion occurs in a herd the first question to arise is "Is it infectious, and if so, to what extent is the infection present?"

Considerable work has been done with the agglutination and complement fixation tests in this disease and many investigators consider them, especially the latter, a very accurate method of determining the presence of infectious abortion in a herd. We believe that with these tests we can determine with a fair degree of accuracy whether infectious abortion is or is not present, but can we determine the extent of infection? What is the significance of a positive reaction? Does it mean

that the animal reacting is infected and even though she carries her calf full time and gives birth to a normal calf she is to be regarded as capable of infecting susceptible animals and should be guarded against with the same precautions as though she had aborted, or may it not be possible that a reaction may indicate acquired immunity and not necessarily infection?

We are making a comparative study of these tests with the object of determining how long a cow may react after abortion. We are also making use of these tests to determine if possible the presence of infectious abortion in herds where the owner requests it.

Our investigations in search of some practical, effective method of controlling the disease are along the line of vaccine treatment, consisting of the injection of dead cultures of the abortus bacillus into pregnant animals and living cultures into non-pregnant animals, supplemented by local applications of cultures of Bact. bulgaricum in cases of abortion. We have about 100 animals in this experiment, a large per cent. of which have received injections of the living cultures. Many of these animals are virgin heifers in infected herds. We have been a little backward in taking the work up on a larger scale since we do not know what pathologic and possibly serious effects these injections may have on the animal. While it is known that cultures of the abortus bacillus do have a very marked pathologic effect on guinea pigs, no work as far as we know has been done to determine their effects on cattle. We are not yet ready to report on this work.

AUTOPSIES AND EXAMINATION OF TISSUES.

During the past year we have conducted 95 autopsies at this laboratory, as follows:

Hogs	74
Cattle	12
Chickens	5
Sheep	2
Dogs	2

Among these we have found:

Hog cholera	26	cases
Acute fibrinous gastritis, hog	10	"
Diphtheritic enteritis, hog	2	"
Pleuro-pneumonia, hog	2	"
Broncho-pneumonia, hog	2	"
Acute gastro-enteritis, hog	2	"
Multiple abscesses of liver, hog	1	"
Central necrosis of liver, hog	1	"
Generalized peritonitis, hog	1	"
Cystitis and rupture of bladder, hog	1	"
Intestinal tuberculosis, cow	2	"
Pulmonary tuberculosis, cow	1	"
Caseous broncho-pneumonia, cow	1	"
Chronic indurative pneumonia, cow	1	"
Generalized vesicular and interstitial emphysema with dilatation of right heart, cow	2	"
Uncinariasis, sheep	1	"
Avian tuberculosis	1	"

A number of specimens of tissue from animals have been sent to the laboratory for bacteriological and pathological examination. In a large per cent. of these cases the tissue is badly decomposed or insufficient material is sent, so that a diagnosis cannot be made. Among the positive cases recorded from the above material we find:

Rabies, cow	2	cases
Œsophagostoma columbianum, sheep	2	"
Actinomycosis, cow	1	"
Hematoma, cow	1	"
Cellular infiltration of arteries, brain of horse (A condition said to occur in forage poisoning).	1	"
Hog cholera	1	"
Sarcoma of testicle, chicken	1	"
Tuberculosis, human	2	"

Among the animal diseases investigated for the Live Stock Sanitary Commission, we record the following interesting cases:

SCOURS OF THE NEW-BORN.

On Oct. 22, 1912, I was called to the farm of Dr. P——— near Jackson to investigate a disease of calves. Since May 17 calves have been born, 11 of which have died within 3 to 4 days of birth with diarrhoea associated with fever and great weakness. The cows are well cared for, are kept in a well lighted, sanitary and comfortable barn of cement construction, in the south end of which are 2 large maternity stalls of cement and steel construction. One of these is used exclusively for calving. I am told that after each case of parturition this stall is thoroughly cleaned, disinfected and that each succeeding case is supplied with fresh, clean bedding. The umbilicus of each calf is washed with a weak iodine solution soon after birth.

At the time of this visit I found one sick calf, age, 9 days. Had had diarrhoea 3 days, fecal discharges of steel-gray color, eyes bright and appetite good. There was one dead calf, age, 3 days. Had been sick 1½ days. Post-mortem lesions on this calf were: Lungs, liver and kidney congested; capillaries of pericardium and mesentery highly injected. Alimentary canal contains very little material, of a yellowish-white color and watery consistency. Mucous membranes congested, umbilical vessels not engorged. Carpal articular sacs contain a small amount of blood-tinged synovia. The tarsal articular sacs contain a somewhat larger quantity of blood-tinged exudate but an inflammatory condition of the articular surfaces is not pronounced.

On Nov. 3, I again visited this farm to autopsy calf referred to above. The calf had been dead only 3 or 4 hours when I reached the farm. Post-mortem lesions were: Calf considerably emaciated, hyperemia of heart and pericardium, and a small hemorrhagic area about 1 cm. in diameter under endocardium of bicuspid valve; liver and kidneys highly congested, bowels constipated, mucosa of fourth stomach, small and large intestines highly injected; mesenteric lymph glands injected, umbilical vessels apparently normal. On both tarsal articulations there is an inflammatory area about 2 to 2½ cm. in diameter. Synovial sacs contain blood-streaked effusion in which is found small flakes, presumably fibrin. The peri-articular membranes are edematous. From the tarsal articulations of both of these cases, a small non-motile, polar-

staining organism was obtained in pure cultures and presented the following characteristics:

Morphological—
Non-motile rod, round ends.
Size. 1.5 to 3.5 microns by .2 to .5 microns, stained with weak solution of fuchsin.
Gram positive. Stains readily with all aniline dyes.

Cultural—
Agar streak: growth abundant, flat, glistening, translucent.
Agar colony: small, round, slightly raised with smooth border, grayish white, translucent.
Gelatin stab: growth best at top, filiform, no liquefaction.
Litmus milk: unchanged.
Plain milk: unchanged.
Nutrient broth: growth uniform throughout. Sediment viscid on agitation, abundant.
Dextrose bouillon: no gas, acid produced.
Saccharose bouillon: no gas, acid produced.
Lactose bouillon: no gas, no change.
Thermal death point 55 C. 10 minutes.
Non-pathogenic for rats, guinea pigs and rabbits. Effects on calves not determined.

LUNG WORMS IN CALVES.

On Oct. 27, 1912, I visited the farm of Mr. H. H. ——————, West Branch to investigate a disease of calves. On this farm I found 17 mature cows, 8 yearlings and 5 calves 5 to 8 months old. Five of the latter were in poor condition, bowels loose, slight cough and rough coat. These calves were running on clover and June grass pasture. Were fed skim milk out of dirty wooden trough and were not housed at night. In pasture were several low, wet, marshy places which are conducive to the propagation of certain animal parasites. Since July, 1912, the owner has lost 8 calves 4 to 8 months of age. The most seriously affected calf at the time of my visit was a heifer 5 months old, considerably emaciated, roughened coat, temp. 104.9, resp. 130 and breathing with much difficulty and through mouth. Whitish discharge from nostrils. Weak, rapid pulse and injected conjunctiva. This calf had been visibly affected about two weeks; had been given three doses of oil and turpentine in last two weeks and was gradually getting worse. In pasture was calf dead 2 days before. Weather was cool and calf fairly well preserved. The only significant pathologic findings were emaciation and a broncho-pneumonia due to the presence of countless numbers of lung worms (Strongylus micrurus) in the trachea and bronchial tubes. In the trachea was a roll of them about as large as the index finger and about three inches long. Bronchial and mediastinal lymph glands were enlarged and edematous.

The treatment suggested was removal of calves from infested pasture, better care and medicinal treatment consisting of infratracheal injections of gasoline. It was suggested that he arrange to place next generation of calves on high dry pasture which had not been used for cattle the previous year, and since some of the older cows are probably

infested with this parasite, that all calves be kept away from older cattle until 8 or 10 months old.

HEMONCHUS CONTORTUS IN LAMBS ASSOCIATED WITH SYMPTOMS OF CENURUS CEREBRALIS.

On Jan. 6, 1913, I accompanied Dr. F—— —— to farm of Mr. W. B. G. near Holly to determine if possible cause of serious loss of lambs. On this farm were about 350 western lambs, housed in 2 separate feed lots. These lambs were bought at the Chicago yards and brought to this farm about Nov. 1st. They were being fed corn silage, hay, and a small quantity of barley (about 1/4 lb. daily per lamb) which was slightly musty. They were watered from a well about 20 rods from barn which was well protected from drainage. About Nov. 21 some of them began to scour but apparently recovered in a few days. On Jan. 4th lambs began to die with the following symptoms: slobbering at mouth, champing jaws, holding head to one side and when forced to move, moved slowly in a circle. There was looseness of bowels. They were sick from a few hours to two or three days before dying. I found several lambs with symptoms as noted above and supposed that some might be infected with Cenurus cerebralis. In three lambs autopsied, the Cenurus cerebralis was *not* found but the Hemonchus contortus was found in each case, not in large numbers, however, probably due to owner having administered several doses of oil and turpentine. This farmer has been feeding lambs for several years. Last year lambs were kept in these feed lots until May 10th when they were sent to market. These lots were not cleaned out during the summer and Nov. 1st the lambs were placed on these dirty lots which were probably infested from sheep fed the past winter. In about three weeks (sufficient time for young parasites taken into the stomach to reach maturity) some of them began to scour but, evidently due to a small number of parasites, none died. On Jan. 4th, these lambs began to die. This was sufficient time (6 weeks) for eggs which were passed from first mature parasites to have reached that stage of development (2-3 weeks) which necessarily takes place in manure, water or moist soil before the young parasites can live if taken into stomach of sheep and sufficient time (3 weeks) for these to reach maturity after being taken up by sheep. The remedy suggested was to clean out feed lots and haul manure to field. Cover feed lots with quick lime and supply clean bedding. Fast lambs 24 hours, then give each lamb 2 drams gasoline in 2 ounces of milk to be followed next day by dose of oil. Repeat if necessary.

HEMONCHUS CONTORTUS IN CALF COMPLICATED WITH GENERALIZED VESICULAR EMPHYSEMA.

On June 18, 1913, I accompanied Dr. S———— of Clarksville to the farm of Mr. H———— to investigate disease of calves. There were 5 calves on this farm from 5 to 8 months old. These were running on a pasture through which a small stream ran, on each side of which was more or less low, wet, marshy ground, shaded by numerous trees and some underbrush. This pasture has been used for cattle for years. There have been no sheep on this farm for many years but the owner

told me that during the lifetime of his father they had at several different times tried to raise sheep but they would all die in the course of a few years. I found three calves visibly diseased. The most serious one presented the following symptoms: Calf somewhat emaciated, temp. normal, resp. highly accelerated and through mouth; calf stood with head slightly extended downward and forward; had severe dry cough, visible mucosae somewhat anemic and bowels loose. I suspected lung worm infestation but on autopsy of this calf to my great surprise not a lung worm was found, but one of the most extensive cases of generalized vesicular emphysema I have seen, and a large number of stomach worms in the abomasum. An interesting question arises in connection with this case: Has the emphysematous condition of the lungs any relation to the parasitic infestation? Probably the most common causes of emphysema are increased difficulty of expiration (as would occur in chronic bronchitis) and diminished elasticity of the alveolar wall. However, in human pathology many cases of emphysema seem to follow cases of malnutrition.

WORK FOR THE LIVE STOCK SANITARY COMMISSION.

Oct. 26. Found calves dying of verminous broncho-pneumonia (Strongylus micrurus) at West Branch.

Oct. 31.—Found hog cholera on farm of Mr. E—— —— S —— near Bancroft.

Nov. 1.—Investigated reported case of suspected glanders at Harrisville. Serum tests negative.

Nov. 3.—Investigated case of white scours of calves on farm near Jackson.

Nov. 8.—Found hog cholera at Litchfield.

Nov. 9. Investigated reported case of suspected glanders near Lennon. Found animal dead and had been buried four days.

Dec. 2. Investigated a disease of pigs on farm of Mr. H near Clinton. Held three autopsies and found each had died with an acute fibrinous gastro-enteritis. Could not ascertain cause.

Dec. 5. Attended meeting of West Michigan Holstein Breeders' Association at Grand Rapids to give talk on the tuberculin test.

Dec. 20. Investigated disease of horses near St. Johns. Diagnosis not made but later diagnosed as influenza. Source of infection probably from band of horse traders that had camped near pasture of this farm.

Jan. 6.—Investigated disease of lambs on farm near Grand Blanc. Owner had lost 35 or 40 within a few days out of a flock of 350. Several sick at time of visit, some of which presented symptoms of "gid." Autopsies on three animals failed to demonstrate the causative agent of "gid" (Cenurus cerebralis) but the twisted wire worm (Hemonchus contortus) was found in the abomasum of each lamb autopsied.

Jan. 10. Found hog cholera on farm near DeWitt. Another farm about one mile distant, the owner of which I saw, had a history of cholera.

Jan. 21. Investigated a disease of horses reported by the supervisor of Monroe township, Newaygo county. One farmer had lost four horses, all that were kept on the farm, within 6 or 7 weeks' time. A farmer on an adjoining farm had lost one head, one other that had

been affected had fully recovered at the time of visit. Diagnosis not made.

Jan. 30.—Visited farm near Sunfield to investigate a reported case of forage poisoning. Farmer owning three horses had lost two, the third one was sick. Temp. 98, pulse 60 per min., weak, but regular, conjunctiva and mucosa of nasal passage injected. Very slight sero-purulent nasal discharge. Bowels constipated. The horse was down and showed no pain, was in a slight comatose condition but at times would manifest some restlessness. The owner informed me that each horse had shown some difficulty in swallowing at the first of the attack. These horses had been fed on silage, corn fodder and corn. The silage was of very poor quality. The corn was over-ripe and no water was used in packing into silo, resulting in a great deal of it spoiling. This silage was also fed to some cattle kept on the farm. A heifer about 18 months old began to show some weakness in the hind limbs and a dullness of expression. A dose of salts was administered and the silage withheld, resulting in recovery.

Feb. 3.—I again visited above mentioned farm near Sunfield to hold an autopsy on horse mentioned above. Lesions: Few hemorrhagic areas in mucosa of fundus of stomach varying in size from 1 to 2 cm. Liver of normal consistency but bile stained. A few localized engorged areas in spleen, maxillary sinuses contain about one-half pint each of sero-purulent effusion. Mucosa of sinuses injected and in places there are grayish deposits of coagulated exudate. Mucosa of trachea and bronchi injected. No effusion into cranial cavity nor into ventricles of brain. Meninges and brain apparently normal.

Feb. 11.—Investigated reported case of tuberculosis among cattle on farm of F. C. M————, Hale. On this farm I found about 25 head of calves and yearlings but no adult cattle, which had been purchased from various farms the previous fall. Prior to my visit, he had lost 3 calves, 4 to 8 months old. A local veterinarian, according to the owner, had pronounced the trouble tuberculosis. I had no reason to suspect tuberculosis of an exceptionally acute type among these young cattle, but found two or three which appeared to be affected with a slight bronchial trouble.

When these calves were purchased they were turned into a large pasture which borders on a lake about one mile wide. The only protection from the cold night winds was an old open house near the lake. I had reason to suspect that some of these calves might be infested with the lung worm (Strongylus micrurus). One calf was coughing quite badly, breathing with some difficulty and somewhat emaciated. This calf was given an intra-tracheal injection of gasoline and a few weeks later the owner wrote me that the calf had stopped coughing and was getting along nicely.

Mar. 8.—Investigated a reported outbreak of anthrax among cattle on the farm of I. C. M————, Forest Hill. Symptoms and post-mortem lesions typical of forage poisoning.

Mar. 12.—Visited farm of Mr. A. H. ————, Shelby to give vaccine treatment for infectious abortion in cattle.

Mar. 21.—Found strangles in livery barn of Mr. N. N. ————, Cadillac.

Apr. 1.—Investigated case of rabies in cattle on farm of Mr. Chas. D———, Romulus.

Apr. 12.—Investigated reported case of glanders on farm of Mr. Fred E——— ———, White Cloud. Found animal not affected with glanders but condition probably due to bad teeth.

Apr. 16.—Found hog cholera on farm of Kalamazoo State Hospital.

Apr. 23.—Investigated reported case of rabies of cow on farm of Mr. C. C. K————, Cassopolis. Found that cow had been buried two days but the brain had been sent to Ann Arbor for examination.

May 7.—Visited farm of J. C. P———, Jackson to give vaccine treatment for infectious abortion.

May 13.—Accompanied Hon. H. H. Halladay to Shelby to inspect carcass of cow that had reacted to the tuberculin test.

May 15. Investigated case of suspected dourine in a stallion at Chelsea. Serum tests, negative.

May 16. Visited farm of J. C. P———, Jackson to give vaccine treatment for infectious abortion.

May 19.—Found so-called cerebro spinal meningitis (forage poisoning) of horses on farm of Mr. J. W. J——, Flowerfield. Out of 13 horses on farm, owner had lost 5 in the past two weeks and 2 were slightly affected at this time. About two weeks previous to this, the owner began feeding hay that had grown on very low ground. The hay was apparently good. He was feeding corn on the cob, some of which was very slightly damaged. I suggested to him to get other hay and shell the corn and float off the decayed and moldy grains on water, also that each animal affected should have a purgative. About one month later I heard, indirectly, that he had had no more trouble.

It is interesting to note that in both cases of this trouble investigated by the writer (see case referred to under date of Jan. 30) the symptoms and lesions observed correspond very closely to those observed in the so-called Kansas Disease. Evidently the cause in each of these cases was the feed.

May 30.—Investigated disease of cattle on farm of Mr. H————, Mt. Pleasant. Owner had lost 3 out of a herd of 21. Symptoms and lesions of cattle described by local veterinarian led us to suspect hemorrhagic septicemia. At the time of my visit there were no affected animals in the herd, consequently a diagnosis was not made.

June 5.—Investigated disease of calves on farm of Mr. M——— ———, Laingsburg. Symptoms and nature of pasture suggested stomach worm but diagnosis was not confirmed as there was no animal available for autopsy.

June 6.—Visited Pontiac State Hospital to confer with Steward concerning infectious abortion of cattle.

June 12.—Visited farm of Mr. P———, near Leslie to administer serum simultaneous treatment for cholera to a herd of 40 hogs.

June 13. Visited farm of J. C. P————, Jackson to give vaccine treatment for infectious abortion.

June 18.—Found stomach worms (Hemonchus contortus) in calves near Clarksville.

June 19. Visited farm of Mr. S————, Rose Center to investigate a disease of hogs. Had lost 5 weighing 125-150 pounds out of a herd of 21. None sick at time of visit. Diagnosis not made.

June 19.—Visited farm of Mr. Wm. W———, Imlay City to investigate a disease of horses. This farm was visited by Dr. Giltner in April, 1910, to investigate this same disease. A report of his investigation is contained in the 1910 report of the State Board of Agriculture. The evidence at hand points to the water as the most probable cause of the trouble, since a change of water will give relief. Strange to say, water from the same well is used by the family without injurious effects. Evidently the water contains an excess of some salt or salts, the effects of which are more pronounced on the horse than on man. We are now having made a complete chemical and biological analysis of the water with the hope of throwing more light on the situation.

Mr. W. S. Robbins has continued in charge of the serum production work and has kept us supplied with a serum of high potency. He has demonstrated the great value of intraperitoneal salt solution injections as a means of greatly increasing the amount of virulent material for hyperimmunization. Mr. Robbins is now making a comparative study of virulent blood and virulent salt solution with a view toward a better understanding of the nature of the latter.

Miss Northrup has started experiments designed to corroborate the results of former experiments to elucidate the uncertain points connected with her investigations with lactic bacteria and a chromogenic acid-destroying yeast. The progress of this work was interrupted by the presentation of a problem that seemed to demand immediate attention. I refer to the possibilities of controlling the ravages of the June beetle larvae by means of a bacterial disease. Miss Northrup appears to have isolated the causal microörganism of this disease and the report of her findings has already been submitted to you for publication. We have already received requests from Porto Rico for a culture of this organism to be used in an effort to control this pest.

Mr. Himmelberger has assisted Dr. Hallman in the investigations relative to infectious abortion and has continued the work on avian tuberculosis which I inaugurated sometime since. Avian tuberculosis has been produced in the calf in two instances and it has been demonstrated that the presence of this disease causes a response to the injection of avian tuberculin with the possibility of no response to the injection of tuberculin usually employed in the diagnosis of bovine tuberculosis. An attempt has also been made to utilize the principle of the agglutination test in the diagnosis of tuberculosis in the domesticated fowl. This work promises well. It would be of great value in high-priced stock. We are quite alive to the fact that poultry diseases in Michigan must be studied for economic reasons.

The commercial work, as for some time past, has been immediately in charge of Miss Rademacher. The importance of this work to the agricultural interests of the state is beginning to be felt. A comparison of the reports for the recent successive years shows the growth of these activities. Miss Rademacher's continued connection with this work ensures satisfaction.

FINANCIAL REPORT ON HOG CHOLERA SERUM MANUFACTURE.

July 1st, 1912—July 1st, 1913.

Feed, concentrated	$ 685.58
Hay, straw and roughage	148.43
Swine	4,930.54
Labor	3,500.00
Travel	5.33
Apparatus and Sundry Items	61.59
	$9,331.47

Value of Receipts and Products on Hand.

Actual receipts for serum and virus	$10,248.66
Actual receipts for pigs	1,822.27
Value of tested serum on hand, 1st class	1,540.00
Value of experimental serum on hand	312.35
Value of unmixed serum on hand	130.00
Value of untested serum on hand	290.00
Value of hogs in work on hand	2,112.50
Value of hogs not in work on hand	128.00
	$16,583.78
Value of products on hand July 1st, 1912	5,968.10
Actual value of products to date	$10,615.68

SERUM.

Total No. cc. on hand good, July 1st, 1912	216,070
Total No. cc. on hand not tested, July 1st, 1912	47,745
Total No. cc. on hand experimental	32,860
Total No. cc. drawn and mixed during year	362,380
Total No. cc. not mixed, on hand July 1st, 1913	12,005
Total	671,060 cc.
Total No. cc. sold, July 1, 1912—July 1, 1913	506,444
Total No. cc. used for testing and experiment	9,555
Total No. cc. mixed and tested serum on hand July 1, 1913	77,000
Total No. cc. experimental serum on hand July 1, 1913	31,235
Total No. cc. unmixed serum on hand	13,000
Total No. cc. untested serum on hand	29,700
Total No. cc. breakage and error	4,126
	671,060 cc.

Michigan	325,006 cc.
Kentucky	77,215 cc.
Maine	29,735 cc.
Ohio	21,445 cc.
Indiana	16,880 cc.
Iowa	8,000 cc.
Massachusetts	6,650 cc.

New Jersey	6,000 cc.
Maryland	5,550 cc.
Alabama	4,963 cc.
Georgia	2,000 cc.
Illinois	2,000 cc.
New York	1,000 cc.
Total	506,441 cc.

TUBERCULIN TEST.

Number of cattle tested for tuberculosis	2,379
Number of cattle reacted	9.2%
Number of cattle suspicious	.6%
Number of doses of tuberculin used during year	3,025
Number of doses of tuberculin still on hand	120
Number of doses not reported upon	160

GLANDERS TEST.

Number of horses tested for glanders	26
Number of horses reacted	0

NUMBER OF LEGUME CULTURES SENT OUT DURING YEAR.

July 1st, 1912—July 1st, 1913.

Alfalfa	5,989
Red Clover	432
Alsike Clover	59
White Clover	6
Pea	127
Cow Pea	133
Soy Bean	101
Bean	148
Sweet Pea	4
Vetch	182
Total	7,181

	Last Season (Full year) Jan. 1, 1912—Jan. 1, 1913.	This Season. (Half year) Jan. 1, 1913—July 1, 1913.
Alfalfa	4531	4101
Red Clover	167	346
Alsike Clover	37	40
White Clover	6	5
Pea	74	126
Cow Pea	89	125
Sweet Pea	1	4
Bean	10	151
Soy Bean	136	100
Vetch	186	70
	5237	5068

OTHER CULTURES.

No. of Alcohol-acetic cultures sent out	14
No of Lactic No. II cultures sent out	7
No. of Bact. bulgaricum cultures sent out	78

We have continued the work with the regular agricultural and short-course students along the line of detailed instruction in tuberculosis (especially bovine) and the tuberculin test. It seems advisable that this work be continued cautiously until we become convinced that the plan is either safe or faulty. From the report of the Bacteriologist for 1910, the following quotation indicates the laboratory's policy: "Such young men are advised to exercise this privilege of testing only in their own community, because it is not hoped to prepare men to devote their entire time to testing, but rather to prepare young men *who can test their own stock* and help their neighbors out when requested." After considerable correspondence with the officials of the federal Bureau of Animal Industry who have kindly furnished us with tuberculin, we find that in a letter dated June 17th, 1913, we are advised by the Chief of the Bureau, "that it has at no time been the understanding of this Bureau that Bureau tuberculin furnished to the Michigan Agricultural College was to be distributed to cattle owners for applying the test to their own herds of cattle." It appears, therefore, that we are confronted with the necessity of manufacturing our own tuberculin, a burden that would have fallen to our lot sooner or later in any event. We are submitting a manuscript for publication in this connection on "The tuberculin tests for tuberculosis in cattle." This has been prepared by Dr. Hallman.

Our official connection with the State Live Stock Sanitary Commission is just terminating on account of the appointment of another as State Veterinarian.

During the past year, the field work and laboratory examinations for the Commission have been done largely by Dr. Hallman. The connection of this laboratory with the operations of the Sanitary Commission has been extended over a great many years, but in recent years the relations have been so intimate and cordial with such evident mutual benefit that it is expected that they will continue. Our activities along the line of hog cholera serum production, tuberculin testing and research into other infectious diseases make this unavoidable.

In conclusion, it is a pleasure to take this opportunity to acknowledge my indebtedness to my collaborators whose work is mentioned herein and to commend them all for loyalty and efficient service. To you also I am indebted for your many acts of courtesy and for your constant support and advice during the past year.

Respectfully,
WARD GILTNER,
Acting Professor of Bacteriology.

East Lansing, Mich., June 30, 1913.

REPORT OF THE CHEMIST.

Director R. S. Shaw, College.

Dear Sir—I herewith submit the following report of the Chemical division for the year ending June 30th, 1913.

CHANGES IN STAFF.

Mr. Arao Itano, assistant chemist, resigned early in the fall to accept a position with the Division of Bacteriology. This vacancy was not filled until June, 1913, when Mr. Arthur K. Hart, a graduate of the University of Michigan, was engaged. During the year Mr. O. F. Jensen a member of the class of 1914, has rendered valuable assistance.

FERTILIZER INSPECTION.

During the season of 1912, 526 samples of commercial fertilizer were collected by inspectors sent out from this office. Of this number 298 samples were analyzed. The results of the inspection emphasize the fact that the manufacturers are very satisfactorily fulfilling the requirements of the law as far as the quantity of plant-food is concerned. In addition to the regular fertilizer analyses we also made a study of the *quality* of the nitrogen contained in the fertilizers and the results show that the nitrogen furnished in many of the commercial fertilizers sold in the state is of distinctly low grade.

This work will be repeated on the fertilizers collected this year after which it is planned to make the study of the quality of the nitrogen furnished in the fertilizers a regular part of the inspection.

During the last session of the Legislature a slight change was made in the fertilizer law but its operation will not be affected.

MISCELLANEOUS WORK.

One hundred and sixty-one samples were analyzed during the year for residents of the state and it is of interest to note that of this number there were 77 samples of marl, limestone and lime products. Many more samples of marl were received and reported upon without being analyzed. A large number of soil samples have been received throughout the year, the largest number in any one day being 19. All of these samples have been tested for acidity and reports made to the senders.

The time of one chemist has been almost completely occupied during the year with the samples sent to the laboratory.

Some time has also been given to co-operating on methods of analysis for the Association of Official Agricultural Chemists. The writer was appointed last fall as referee for the association on the determination of phosphoric acid in Basic Slag.

For the Horticultural division, complete analyses were made of the fruit, leaves and new wood of 2 varieties of gooseberries, and 3 varieties of currants, in order to determine the amount of plant-food removed from the soil by each variety during the season. This alone necessitated the making of more than 200 separate determinations.

A new and simple method for determining the neutrality of Ammonium Citrate solutions was worked out and reported at the meeting of the American Chemical Society held in Milwaukee March 25-28th.

HATCH FUND.

A study of "Soil Acidity" has been made during the year and we were fortunate in securing Dr. J. E. Harris, an instructor in the Chemical department at the University of Michigan, to work upon the problem during the summer and winter vacations. The importance of this problem is better appreciated when we realize that probably 50% of the soils in the lower peninsula are acid, and many cases of infertility are due to this cause alone. The nature of the soil acids is but little understood although it has been one of the problems facing the agricultural chemist for many years. The importance of the problem should justify a much more exhaustive study of it and in view of the results already obtained by Dr. Harris, in the limited time he has been working on the subject, I respectfully recommend that he be engaged as a regular research assistant in the division to continue the work.

A study of the influence of osmosis upon the movement of water in soils has been made by Mr. Robinson and the results obtained justify a continuance of the work, and I recommend that it be made an Adams project.

ADAMS FUND.

But little progress has been made on the Adams project 2b owing to lack of assistants. The outline for an extensive study of the subject has been made and will be undertaken as soon as possible.

Considerable progress has been made on project 2ba, which will be reported in a technical bulletin soon to be prepared. The manuscript for a popular bulletin embodying some of the results of this investigation has been prepared and will be presented for publication in the near future. In connection with this investigation some co-operative experiments are being planned to demonstrate the value of muck and peat as a substitute for manure for use on the lighter soils of the state. This is a very pertinent investigation since the cost of getting manure in some parts of the state makes its use almost prohibitive. If it can be demonstrated that muck or peat, found abundantly in all parts of the state, can be substituted for manure one of the greatest problems of the farmer will be solved.

In conclusion I wish to record my appreciation of the faithful and diligent work of my associates, to whom credit is due for much that the division has accomplished during the year.

Very respectfully,
ANDREW J. PATTEN,
Chemist.

East Lansing, Mich., June 30, 1913.

REPORT OF THE DIVISION OF FARM CROPS.

Director R. S. Shaw, College.

Dear Sir—I wish to submit the following report of the Division of Farm Crops for the year ending June 30th, 1913.

CROP IMPROVEMENT.

The most important line of investigation carried on by the division is that of Crop Improvement, which has been under the able direction of Mr. F. A. Spragg who reports upon this work as follows:

"The wheat crosses made last year have come through the winter in good shape and are in head. There are twenty-four of these crosses, representing combinations of our better varieties that have given good quality and yield and endured the winters of 1911 and 1912.

Besides crosses in wheat the Station has over a hundred plats representing crosses in barley and oats.

The winter barleys have a better stand and general vigor than the wheats growing along side. In another year we will have a chance to increase these to a point where they can be sent out to farmers.

The pedigreed ryes have much larger, better filled heads than the common sorts. When we come to think of it, it is surprising how many poorly filled ryes there are in the country. If all the rye flowers fertilize and produce grains there should be four rows of grains on a head. Most commercial ryes have very small heads and besides this very little more than two rows of grain on a head. The average yield for rye in the United States is 15 bushels per acre. The Station's pedigreed ryes yielded about 45 bushels per acre in 1912.

In 1913 there are 20 spring barley plats, 5 winter barley plats, about 170 oats plats, 6 rye plats, 4 spelt plats, and over 200 wheat plats.

A new 4000 plant alfalfa nursery has just been set out. The mothers of these plants have stood two ice sheets, produced a good amount of hay, and also seed in 1913. This nursery should represent the cream of all the 160 lots of alfalfa that have been tested and selected at the Station.

The timothy plats have been very interesting this year. Eighty-four strains were selected out of over 2000 last fall. These selected lots are growing in rows, in comparison with commercial timothy.

Seventy-two varieties of peas are being tested in rows, making with the checks 90 plats. These were imported by the U. S. Dept. from various parts of the world. They are an interesting set of plats now.

In corn besides the ear-row test, a large number of crosses are being made to test relative value of first-generation crosses as compared with the original sorts."

The experiment in testing varieties of corn has been continued in much the same way as in previous years. Through this experiment and the co-operative tests carried on throughout the state several varieties have been discovered which give promise of being much more productive, and much better adapted to Michigan conditions than the mongrel and unselected varieties commonly grown. In several instances co-operators

are planting their general crop to improved varieties which made a good showing in earlier tests. The department is getting into a much better position to make recommendations as to choice of varieties for different sections and different types of soil. In some sections, however, the information on this point is still limited and there is a dearth of seed corn of improved and adapted varieties.

ROTATION AND FERTILIZER EXPERIMENT.

The rotation and fertilizer experiment which was started in field 9 in 1911 has been continued as originally planned. While the differences between the different plots has not in all cases been great, they have been sufficient in many cases to indicate strongly the value of the experiment. After the courses have been repeated several times, some valuable object lessons should be had as to the use of manure and fertilizers and the effect of the different crops upon each other.

There are perhaps more variable factors in crop production than in any other phase of agricultural work. Because of this fact and the local nature of many of these problems it has not been thought best to inaugurate at the Station extensive experiments in many lines of crop production work. It is important, however, that these problems be studied in different sections of the state by competent field men and bulletins prepared which shall discuss various farm practices, methods of culture, varieties, seed selection and other practical subjects. It is hoped that provision may soon be made for taking up this work more extensively than has been possible in the past.

Respectfully submitted,
V. M. SHOESMITH,
Farm Crops Experimentalist.

East Lansing, Mich., June 30, 1913.

REPORT OF THE SOIL PHYSICIST.

Director R. S. Shaw, East Lansing, Michigan.

Dear Sir—During the year just closed no material changes have occurred in the operation of the Soils department. Dr. Bouyoucos has carried forward his work in the investigation of the temperature of soils. The results obtained will be embodied in Technical Bulletin No. 17 now on the press. I am convinced that the results reported in this bulletin will prove of both interest and value to the student of soils.

As the work of investigation has progressed other questions have arisen which will call for further investigation along these lines. Dr. Bouyoucos left the college about the middle of June to spend a year in advanced study in this country and abroad. On his return he will take up and continue the work which he has thus temporarily dropped. Matters have been arranged, however, so that during his absence observations may be made and records kept of temperature variations under various field and artificial conditions preparatory to the continuation of the investigation work on his return.

During Dr. Bouyoucos' absence his place will be temporarily filled by Mr. P. E. Karraker. Mr. Karraker will have general direction of the observations above referred to, but will devote the major part of his time to a new line of soil investigation. This will be a study of some of the factors involved in capillary movements of soil water.

Mr. Spurway's time has been so fully employed with teaching and extension work that he has been able to do little in the way of investigation. From time to time in his instructional work questions have been suggested which have called for some work along this line, and have perhaps bared clues which may lead later to interesting conclusions.

For some years past this department has felt the need of greenhouse facilities for carrying on certain of its soil investigation work. The need for such facilities is increasing. It is to be sincerely hoped that some provision can be made in the very near future by which this department may be equipped, even though in a limited way, with such facilities.

In submitting this, my last report, I desire to express my sincere appreciation of the uniform consideration and kindness received at your hands during the years of our association.

Very respectfully,
JOS. A. JEFFERY,
Soil Physicist.

East Lansing, Mich., June 30, 1913.

REPORT OF THE BOTANIST.

Director R. S. Shaw.

Dear Sir—I herewith submit the report of the work of the Botanical division for the year ending June 30, 1913.

The staff has been the same as at the close of the preceding year, viz: Dr. R. P. Hibbard, Research Assistant in Plant Physiology and Professor G. H. Coons, Research Assistant in Plant Pathology.

Professor Coons was absent on leave to study at the University of Michigan a portion of the spring but returned to work about the middle of June.

The work that has been undertaken and accomplished by Professor Coons and Dr. Hibbard is reported on more in detail in special reports from these two which are herewith appended and made a part of my report, together with an article by Professor Coons on the use of the pneumatic chisel for pruning purposes which I would recommend be printed with the report.

Considerable apparatus along the line of plant physiology has been added so that the equipment along that line is very excellent.

Respectfully submitted,
ERNST A. BESSEY,
Botanist.

East Lansing, Mich., June 30, 1913.

Prof. Ernst A. Bessey.

Dear Sir—At your request I submit a report of the work done during the past fiscal year. My work, aside from the work done in the col-

lege, falls under two heads; that done on the Adams project and work done in accordance with the Hatch fund.

Work Under Adams Fund.—A formal statement of the Adams project is: A study of the limb and twig diseases of two fruit trees. A serious canker of apple has occupied my attention. This disease was found in several places in the northern part of the lower peninsula and during last July, field studies were made on its prevalence, the amount of damage and varieties affected. Control measures were tried in two co-operative experiments and these have yielded decisive results. The causal organism has been isolated, grown in pure culture, inoculated into apple and pear trees and reisolated. At present the disease is being studied under the following lines:

(a) Cultural characteristics of the disease producing organism.
(b) Relation of the fungus to the host.
(c) Practical control measures.

In the line of practical control measures the pneumatic hammer has been utilized to drive a chisel and the usefulness of this tool for the eradication of cankers and for tree surgery is reported in a separate article which is to be printed with this report. Attention is also being paid to various paints and wound coverings which may be found suitable for use in covering wounds made by cutting out cankers and which will not interfere with the normal wound callus formation.

Work Under Hatch Fund.—The plant disease survey of the state has been continued and state correspondence on plant diseases answered. One publication "A Preliminary Host Index of the Fungi of Michigan, Exclusive of the Basidiomycetes, and Including the Plant Diseases of Bacterial and Physiological Origin" has been published in the 14th report of the Michigan Academy of Science (1913). The annual report of the plant disease survey of the state has been made under your direction. Field experiments have been made in the control of various potato diseases and an attempt was made to determine accurately the extent of damage done by Late Blight of the potato last year. The results of this work are included in a manuscript which was submitted in April to the director of the experiment station. A manuscript is in preparation upon the relation of *Phytophthora infestans* (Mont.) De Bary, to the weather.

A co-operative experiment in the control of Fire Blight of apples was undertaken at the farm of Miss Martha Wilson of Charlevoix. A survey of the orchard was made, and a senior student, Mr. J. A. McClintock was sent at Miss Wilson's expense to cut out the cankers and blighted twigs. An examination this spring shows that although over 200 cankers were cut out, only 5 limbs developed the disease this year.

The Botanical division of the experiment station is cramped for room. High pressure steam is needed for ready operation of several pieces of apparatus. The specimens sent in by farmers throughout the state, and those collected during field trips are increasing in number and a proper housing for these should be provided. It might be well to have these arranged by hosts according to the plans followed by other experiment stations, and soon the specimens would form a valuable reference col-

lection on the diseases of Michigan, both as to nature and distribution. For comparison the standard European collections of fungi are badly needed.

Respectfully submitted,
G. H. COONS,
Research Assistant in Plant Pathology.

THE PNEUMATIC CHISEL APPLIED TO TREE SURGERY, CUTTING OUT CANKERS, AND PRUNING.

BY G. H. COONS, RESEARCH ASSISTANT IN PLANT PATHOLOGY.

In tree surgery, it is necessary to open cavities, cut off broken, splintered stubs and clear away decayed wood down to a sound base. In pruning, it is necessary, in order to prevent the retardation of the wound callus, to avoid stubs and to make all pruning flush with the main branch. Much of the work in cutting out cankers, requires a tool such as a carpenter's gouge. These operations of tree surgery require much work and some jobs require hours of chipping with the chisel and mallet.

It was thought worth while to attempt to devise a means of cutting down the labor entailed in these operations, and the pneumatic hammer driving a chisel was experimented with as a cutting tool.

To the author's knowledge, no other tool to do similar work has been devised. There is, however, a rotary cutter driven at high speed by a gasoline engine or other power, which is being perfected by Dr. G. E. Stone[1] of the Massachusetts Experiment Station. This rotary cutter may become a valuable adjunct for tree surgery since it makes the cleaning of cavities easy.

The pneumatic tool is an adaptation of the pneumatic hammer used in riveting and chipping, and in it the chisel is held and advanced by the numerous (twenty-eight hundred per minute) blows of the piston which is driven by compressed air.

In these experiments, the pneumatic hammers were attached to fifty foot lengths of heavy-walled hose carried from a 66 gallon range boiler which served as the reservoir for air. Air pressure of fifty pounds or over was maintained. This pressure was given by a one and one-half horse power gasoline engine working an air-cooled pump. The method of assembling the trial outfit is shown in the accompanying cut. Fig. 2. The tables accompanying this article will give, for the size of the hammer used, the volume of air required by each and a consultation of the catalog of any firm making air compressors will give the capacity of the different sizes of pumps.

The chisels used were specially made and were on the order of a carpenter's gouge. One was fashioned from a rasp and was bent to a crescent shape, while the other was hammered out from tool steel to

[1]G. E. Stone in Start, E. A., Stone, G. E., and Fernald, H. T., Mass. Exp. Sta. Bul. 125:6 3 pp., 1 fig.

give a 1″ cutting edge. This, when ground to an edge, beveled on the inside, gave very good results.

Size and style.	Diameter piston.	Length of stroke.	Blows per min.	Cu. ft. of free air per minute.	Power test.	Length over all.	Net weight.
Boyer Chipping & Calking BB....	1 1/16	1 1/2	2800	12	.03387	11 1/2	9
Boyer Stone F...	15/16	1 1/4	2200	8	.02004	10	6 1/2
Boyer Stone O...	11/16	3/4	3200	7	.00890	8 3/4	4 1/2

Three different weights of pneumatic hammer were tried, Boyer BB, weight nine pounds, Boyer F, weight six and one-half pounds, and Boyer O, weight four and one-half pounds. It was thought at first that only by considerable weight could the rebound be taken up, and hence a heavy hammer was chosen. While this was found very effective, its weight with that of the length of hose to be lifted made its use very tiring. Accordingly two lighter weight hammers were secured and were found to work very well. The lighter hammers give more of a jar to the hand, but this, however, is not enough to interfere with their use. The extra portability and lightness of the smaller sizes make them by far preferable for this work.

The method of operating the chisel is very simple and one can become skillful with it in an afternoon. It is seen from the cut that the chisel is shaped like a revolver, with the air-throttle valve situated above the hammer and under the control of the thumb. After projecting parts of the wound are hewn away and for this a lather's hatchet is excellent, the opening of the cavity is made with the chisel. This chisel is held firmly against the wood with two hands and the material chipped away. Only solid wood can be cut since splinters or any small branches vibrate to and fro with the hammer.

The chisel should be fastened in the hammer by means of a set screw or a firm grip chuck in order that it may not drop out.

It was very soon found that the pneumatic chisel will not replace the hammer and saw and hence the gross work of pruning and cutting must be done as before. The pneumatic tool does do the work of gouging out cankers, smoothing stubs flush with the face and opening cavities very effectively. In short, it does exactly the work of the gouge and the mallet.

Careful timing of similar jobs shows that after one becomes proficient in the use of the tool, he can do four or five times more work with it than can be done with the mallet and gouge.

This tool is recommended to tree surgeons, park boards and city foresters doing tree surgery work and to fruit growers with large acreages.

The equipment can most economically be made a part of the spraying outfit, by placing the air pump on this outfit and slinging the tank underneath the trucks, or setting it upright beside the spray tank.

The fittings required to make up the pressure system consist of the check valve and piping between the pump and the tank, the hose connections, cut off valve and gauge between the hose and the tank. Park boards buying new spray equipments can save time and secure better

arrangements by having this air compressor and tank put on the machine at the time of purchase.

The author has found the following advantages in the use of the tool:

It does the work of opening cavities, pruning away stubs, cutting off broken splintered limbs—the work which at present requires the mallet and chisel—very effectively.

It must be confessed that the ordinary fruit grower, other than sawing as close as is possible, makes no attempt to make wounds flush, this tool, since it renders this work easier, should do much to encourage a better class of pruning.

It does the work of four or five men and the work of holding the pneumatic hammer is not so tiring as the use of the mallet and chisel.

It is an excellent means of cutting out limb cankers such as are made by pear blight, New York apple tree canker and the like. Rightly used, it should save many limbs which otherwise would be girdled in a short time.

Given to a city forester or a park board, it will make possible the repair of the trees of a whole street where, at present, only a few blocks can be handled.

The cost of this outfit, as used in this experiment, which gives air enough for the operation of two small hammers, is about one hundred dollars, exclusive of the engine. This estimate places the hammer at from \$35.00 to \$40.00, depending on size; pump at \$34.00; the tank at \$15.00, with the hose at twenty cents per foot.

The number of hammers to be operated from one air supply and the size of pump, engine, etc., must be decided for each particular case. Furthermore, the chisels, gouges, etc., must be fashioned to suit the particular class of work to be done.

The author wishes to thank the Chicago Pneumatic Tool Company of Detroit for the loan of the tools used in the experiment and the Department of Farm Mechanics for assembling the outfit.

In conclusion, it may be well to point out that this use of the pneumatic chisel is new and is as yet in the experimental stage. This tool does the work of the chisel and mallet, not that of the axe or saw. As tried on trees on the M. A. C. campus and in an apple orchard nearby, it did very efficient work. It would seem that the recommendations in light of this experience were justified and it is hoped that the tool will find a wide use.

Prof. E. A. Bessey, East Lansing, Michigan.

Dear Sir—I have the honor to submit herewith a report of the Plant Physiological studies for the year 1912-13. Outside of the time used for instruction, my work has been entirely on the Adams Fund work.

The problem in its broadest sense is a problem of *Nutrition.* The role of salts in the growth and development of plants is obviously a highly important problem. Of the class of organic foods we know much but as to the function of the other class, salts, we know very little beyond the fact that neither plants nor animals can live on an ash free diet. Botanists and soil chemists have assumed that salts are of nutritive value since the elimination of one or more elements from the solutions interfers with the vital activities of the plant. Animal physiologists have recently shown that some salts function in a protective way rather than in a nutritive one. Not only is this true for some few marine animals but also for a few plants.

According to this hypothesis one salt antagonizes or neutralizes the toxic effect of another and a certain balance or equilibrium is attained in the solution. The blood of animals, sea water and in all probability the soil solution are *physiologically balanced solutions.* If this view of the role of salts finds substantiation by further studies it will, in all probability, lead to problems of great value to the farmer, for it is an accepted fact that the soil solution which bathes the root hairs is the direct source of the mineral elements which the plant receives, and one may also justly conclude that the soil solution is a physiologically balanced solution for such plants as thrive on the soil from which the solution was derived.

In spite of many investigations it is not yet clear what constituents of the soil are absolutely needful for plants in a nutritive sense. For example, lime, one of the most important elements, in all probability exerts a protective or corrective function. The bulk of experiments on the application of fertilizers and even our general agricultural practice fail to consider the effect of such fertilizer treatment on the *soil* solution. The present methods are not based on the principles of *balanced solutions.* The phenomenon of adsorption undoubtedly plays an important role in all soil problems and what relation this holds to the subject of *balanced solutions* is as yet to be determined. Whether, among other factors, it helps to attain a balance in the soil solution or not is of fundamental value.

The problem as roughly outlined above has been so far of laboratory nature and has led to the publication of a preliminary paper entitled "The Antitoxic Action of Chloral Hydrate and Copper Sulphate for *Pisum sativum.*" This paper appears in the Central blatt fur Bakteriologie. Already experiments have been started in the field and for this purpose we are using the large zinc cans imbedded in the soil. Much of the work has been a study of methodology or the improvements in such. It is gratifying to report therefore, upon another paper which will appear in preliminary form in the Fourteenth Report of the Michigan Academy of Science. This method contemplates a radical change in the ordinary Kohlrausch method in that a dynamometer actuated by an alternating current supercedes the old telephone and induction coil. In co-operation with Prof. C. W. Chapman of the Physics department a complete report on this improved method is being put into shape for publication according to the director's wishes. In this paper the different methods are compared to relative accuracy, quickness and ease of manipulation.

The work of teaching in the college engrosses more and more time although three fourths of my time should belong to the Experiment Station. This could be readily avoided if facilities were at hand such as a storekeeper, and laboratory assistant could provide to take care of certain routine parts of the laboratory work in teaching.

Respectfully submitted,

R. P. HIBBARD,

Research Assistant in Plant Physiology.

East Lansing, Mich., June 30, 1913.

REPORT OF THE ENTOMOLOGIST.

Director R. S. Shaw.

Dear Sir—Following is a brief report of the work of the Division of Entomology for the year ending June 30, 1913.

The cold, wet spring of last year led to the development of a serious aphid out-break, which had its effect on the apple crop especially. The spring just past has repeated the conditions of a year ago, only in lesser degree, and the present summer finds lots of plant-lice in the orchards. It is very exceptional indeed to have two aphid years in succession. In the northern part of the state the weather turned hot when summer finally came and the grasshoppers have in consequence been unusually abundant.

As in the past, new pests are continually coming in, and these often require rearing to make sure their identity. The correspondence grows yearly, and as a consequence more effort is expended to take care of inquiries.

During the year, a revised edition of the Spray and Practice Outline was prepared by Professor Eustace and the writer, and published as special bulletin No. 61.

Dr. G. D. Shafer is still working on his problem concerning how contact insecticides kill insects, with gratifying results. His experiments are gradually focussing on some principles of basic interest.

It is hoped that during the next year, we shall be able to take up more of the work of insect control, such as is brought about by spraying, etc., due to the promise of part of the time of a new man for this work.

The writer is using such time as can be secured at present to apply on a bulletin on the principal forest and shade tree insects of Michigan.

Respectfully submitted,
R. H. PETTIT,
Entomologist.

East Lansing, Mich., June 30, 1913.

REPORT OF THE HORTICULTURIST.

Director R. S. Shaw.

Sir—I herewith submit a report on the work in horticulture for the year ending June 30th, 1913:

Bulletins or circulars from this department have been issued on "Cover Crops for Michigan Orchards and Vineyards," "Celery Growing," "Small Gruit Culture," "Cucumbers as a Cash Crop," "Starting a Lawn" and "Spray and Practice Outline for Fruit Growers." That the information contained in these publications has been of value can best be judged by the demand for them. The circular on "Cover Crops

for Michigan Orchards and Vineyards," though printed in a liberal edition, was soon exhausted and should be reprinted soon.

A number of experiments that will require several years to obtain results were started a few years ago and nothing definite can be reported upon them at this time. These experiments include tests to determine the comparative merits of pruned and unpruned young fruit trees; of the value of the Kieffer pear as a stock for top working other varieties; tomato breeding; strawberry breeding; the value of peach trees when propagated with buds taken from trees of unusual vigor; fertilizer tests for tomatoes at Plymouth; value of different stocks for sour cherries.

A test was again made to determine the value of spraying potato plants with the Bordeaux mixture and poison. The gain in yield was barely enough to pay for the spraying but the tubers from sprayed plants were kept in better condition for a longer time than those from plants not sprayed.

A careful test was made for two seasons on the comparative value of Bordeaux mixture and the diluted commercial lime and sulphur for spraying cherry and domestic plums to control leaf spot and rot. The Bordeaux was made with four pounds of copper sulphate and six pounds of lime to fifty gallons of water. The concentrated commercial lime-sulphur tested 33 Baume and one gallon was diluted with water to forty gallons. Arsenate of lead was used as needed. There was no noticeable difference in the efficiency of either of these mixtures while adjacent trees not sprayed were completely defoliated by mid summer and the fruit of no value.

A comparison of the efficiency of copper sulphate solution (1 pound of copper sulphate to 10 of water) and one gallon of concentrated lime-sulphur, 34 Baume to 44 gallons of water to check peach leaf curl resulted very much in favor of the lime-sulphur. Where San Jose scale is present, the lime-sulphur will have to be used and if the spraying is made before the buds break, the leaf curl will be controlled and the San Jose scale destroyed but in regions where the scale is not present, these results indicate that it is better to use the lime-sulphur to prevent the leaf curl than the copper sulphate solution.

In an effort to determine the value of winter vetch for an orchard cover crop, plots one acre in size in orchards in various parts of the state, mostly in the northern part, were sown during late July or early August. Notes were secured upon the appearance of the vetch in May and in every case where the soil was sandy, the crop was very successful. This plant is still highly regarded for an orchard or vineyard cover crop.

A test on thinning Wealthy apples was made in an orchard near Grand Ledge. On a tree where the fruit was not thinned by actual count there were 2913 fruits of which 2213 were number ones, making 17 bushels, 180 culls and 250 drops. An adjacent tree that required one hour and forty minutes of labor to thin the fruit on July 22nd, there were 2085 fruits, 1965 of which were number ones which made just 17 bushels and 120 culls and drops. These two trees are taken for comparison since the yields of No. 1 fruit was exactly the same and the results are typical of the others. Where the crop of fruit is good, there is no question but what thinning the fruit in the early summer is a very profitable orchard practice. It not only results in a much more

valuable crop of fruit but in many instances, the tree is saved from serious injury by having the load of fruit evenly distributed over the tree.

It is hoped in the near future, to have ready for publication bulletins on "Peach Growing" with a complete financial account of a fifteen acre peach orchard now six years old and on "Tomato Growing" including the results with various fertilizers, spraying mixtures and methods of culture.

The Experiment Station work in horticulture is and for some years, has been very seriously handicapped in the progress that should have been made for the reason of insufficient help. With college duties occupying the time of every member of the department and each year becoming heavier, it has been impossible to give the time to Station work that it has been desired and should be given. Another year, it is hoped an assistant can be employed to give his entire time to the Station work.

Respectfully submitted,
H. J. EUSTACE,
Horticulturist.

East Lansing, Mich., June 30, 1913.

ANNUAL REPORT OF THE SOUTH HAVEN EXPERIMENT STATION.

Prof. H. J. Eustace, Horticulturist.

Sir—The following report upon the work of the South Haven Sub-Station is herewith submitted.

Owing to the crowded condition of the trees, it has been necessary for us to remove many of them during the past few years in order that the remaining ones might receive plenty of sunlight and also to facilitate the orchard operations such as spraying and pruning. This has lessened, to some extent, the number in our list of varieties but where there has been any preference, we have removed varieties of the least importance so that our collection still contains the best varieties which have been started here.

Varieties.—At present, the total number of varieties on the grounds is 677. Of this number, 210 are apples, 88 plums, 82 cherries, 87 pears, 68 peaches, 51 grapes, 24 nuts, 8 quinces, 14 currants, 13 gooseberries, 8 red raspberries, 7 black raspberries, 3 purple raspberries, 13 blackberries and 3 dewberries.

Among the new and little known varieties of apples which are doing well in the Station orchards are the No. 1 New, Winter Banana, Fameuse, Sucre and Spencer. Traveler, Star and Wells are also new varieties which have just come into bearing and all promise well.

Number 1 New is one of Gideon's seedlings. It is a Russian apple of the Duchess type and ripens at about the same time. It is very prolific, bearing large crops biennially and the tree is a more vigorous grower than the Duchess. The fruit is larger and firmer than the Duchess but is generally not as highly colored. It is worthy of a trial for those who wish another variety which ripens at that time of the year.

Those who wish to try a new variety of the Fameuse type will be pleased with the Fameuse Sucre. The fruit is of better quality and has a higher color than the Fameuse but is not quite as large and the keeping qualities are not as good.

For a very early peach, the Mayflower has proven desirable with us. It is a large white cling-stone peach of fairly good quality. The bright red cheek gives the fruit a good appearance. It will probably not be of much value as a commercial variety but should have a place in the home orchard as it ripens about the twentieth of July which is some time before any of the other varieties ripen.

In our test of nut varieties, we have found several which are worthy of consideration by those interested in nut growing. The Paragon and Comfort Chestnuts have done very well with us. Both varieties bear good crops almost every year. The Paragon is, by far, the better of the two and should be raised by every one who wishes to grow something besides the native nut. Although the trees are rather small in size, the crop will often average a half a bushel of nuts to the tree. A number of Paragon seedlings were set this spring. Chinquapin chestnuts have not given very good results. They have not produced any fruit and are not very vigorous growers.

The Kentish Cob and the Cosford Thin Shell filberts have given good results. Both bear quite well and the nuts are fine, large and meaty. The crop averages about a fifth basket of nuts per tree and sometimes a little more. The Kentish Cob is the best variety of the two as the nut is larger and the bush more prolific.

The English hazelnut bears fair crops occasionally but the nut is small and the filbert would be preferred if this type of nut is to be grown.

Two pecan trees set in 1890 have made enormous growth but did not blossom and set fruit until last year. The season here is not long enough to mature the nut. The trees have been perfectly hardy, being apparently uninjured by the freeze of 1906 and the cold winter of 1911-12.

Soil Culture Tests.—In 1907, a comparative test of sod mulch and cultivation was started in blocks of European plums, Japanese plums and apples. In each case, except the Japanese plums, the blocks consist of three rows of twelve trees each, each row being set to a different variety. The plots are so arranged that each consists of three varieties with six trees of each variety. In the Japanese plum block, there are four rows and an equal number of varieties. The varieties in this block are the Burbank, Abundance, Satsuma and Red June.

The varieties in the apple block are the Wagener, Wealthy and Duchess and in the block of European plums, the varieties are the Monarch, Grand Duke and Bradshaw.

The following figures give the average circumference of the trunks of the trees at a distance of one foot from the ground and also the average length of the growth made by each variety this year (1913):

	Sod Mulch.		Cultivation.	
	Circumference.	Length.	Circumference.	Length.
European Plums:				
Grand Duke	5.1 in.	15 in.	6.66 in.	13.1 in.
Bradshaw	6.54 in.	13.27 in.	6.46 in.	13.8 in.
Monarch	7.83 in.	13 in.	8.55 in.	11.3 in.
Japanese Plums:				
Burbank	8.3 in.	13.25 in.	8.55 in.	15.4 in.
Satsuma	5.9 in.	9.35 in.	7 in.	13.4 in.
Abundance	7.74 in.	10.2 in.	8.4 in.	10.75 in.
Red June	6.4 in.	14.8 in.	6.5 in.	11.3 in.
Apples:				
Wagener	3.87 in.	9.25 in.	4.81 in.	14.8 in.
Wealthy	5.62 in.	12.3 in.	7.1 in.	14.25 in.
Duchess	5.08 in.	12.6 in.	4.81 in.	16.1 in.

From the above measurements, it can be readily seen that the trees in the cultivated plots have grown the best. The rather mixed results in the case of the European plums is due to the fact that the cultivated plot was affected by a row of shade trees and a hedge which drew the plant food and moisture from some of the fruit trees. Had it not been for this, it is certain that the trees in the cultivated plot would have made a much better showing.

The difference between the cultivated and sod mulch plots was not very noticeable until two years ago. In fact, Japanese plums, in the sod mulch plot seemed to be doing the best. Now, the difference in favor of the cultivated trees is growing greater every year.

The general care of the cultivation and sod mulch plots has been according to the accepted methods of each kind of culture. In the sod mulch plot, the grass was cut twice a year and enough mulching put around the trees, as far out as the drip of the leaves, to kill out all growth of grass and weeds. Extra mulching material was brought into the orchard if necessary.

In the cultivated plots, the ground was plowed early in the spring and kept cultivated until about the first of August. It was then sown to a cover crop of common red clover, except the last two seasons, when oats were used instead of the clover as it was found that the continual use of clover was too stimulating to the growth of the trees.

May Frost.—The frost of May 9th did considerable damage to the present season's fruit crop. At that time, the thermometer registered 27 degrees. Along the lake shore, the apples were not materially injured although some growers have reported damage to those varieties which were just through blossoming while those which were in full bloom are bearing good crops. The difference, if any, in the effect of the frost on varieties, was very slight. It was apparently more a matter of location and condition of blossoming.

The Bartlett pears, however, were more susceptible to frost injury than other varieties of that fruit. Of the peaches, Smock, Salway and Kalamazoo were apparently the most affected. Elbertas and Gold

Drops generally have good crops. In our orchards, Lemon Free, Whitford, Uneeda, Cling and Red Bird Cling have the best crops. There was apparently no difference in the effect of the frost on varieties of cherries and plums.

There is a continuing increase in the number of requests for information both by correspondence and telephone calls. A large number of the questions are with reference to spraying and much interest is manifested in our work of determining the proper time to spray for the codling moth.

The large number of requests for personal inspector of orchards where conditions are not normal cannot be granted on account of the lack of time.

F. A. WILKIN,
Superintendent.

South Haven, Mich., June 30, 1913.

REPORT OF THE DAIRY HUSBANDMAN.

To Director R. S. Shaw, East Lansing, Mich.

Dear Sir— The following brief statement is submitted as the report of the Dairy Husbandman for the year July 1, 1912, to July 1, 1913:

All the experimental projects under investigation have been continued throughout the year. Considerable progress has been made with the grade dairy herd, and, barring unfortunate occurrences, we hope to bring this work to a close in the next three or four years.

Data has been collecting, and is now nearly completed, for a bulletin on the variation of the butter fat content in the milk of individual cows.

Tentative plans for two lines of experimental work submitted a year ago have been revised from time to time, and it is hoped, with the present funds available, to actually begin the work along both these lines within the next six months.

No bulletins have been written or published during the past year.

Respectfully submitted,
A. C. ANDERSON,
Dairy Husbandman.

East Lansing, Mich., June 30, 1913.

BULLETINS

OF THE

Agricultural College Experiment Station

ISSUED DURING THE

YEAR ENDING JUNE 30, 1913.

WHEAT IMPROVEMENT.

Bulletin No. 268.

BY FRANK A. SPRAGG.

MICHIGAN WHEAT CONDITIONS.

If one should walk into the average wheat field in Michigan just before harvest, he would find occasional heads of a large number of types of wheat. Some of these might perhaps have a white chaff, some a red chaff, some might be bearded and some beardless, and if a number of heads were shelled differences would also be found in the grain such as hard, soft, red, white, etc. The writer has counted as high as a dozen types of wheat in one field. This shows that the farmer is growing a mixture of at least that number of varieties.

As can be seen in Fig. 1, Michigan is not producing the quantity of wheat that she should, were all her farmers practicing proper methods of culture and growing the best variety for their soil and conditions.

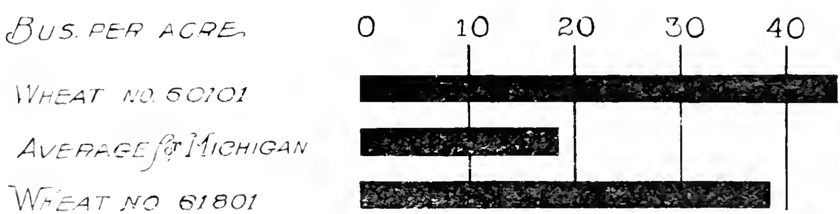

Fig. 1.—Showing the relative yields of two of the better varieties at the Michigan Experiment Station as compared with the average yield of the state.

Michigan is producing about half as much wheat per acre as she should. The average yield of wheat in Michigan for 1910 and 1911, as reported in the Yearbook of the Department of Agriculture, was 18 bushels per acre. Wheat No. 60101, which is a selection from the American Banner produced 42.8 bushels per acre and No. 61801, which is a selection from the Shepherd's Perfection, 39.3 bushels per acre as an average for the same two seasons. No doubt many of the low yields that cut down the state's average come from a class of careless farmers who continue to plant year by year any kind of wheat that they may happen to have. These farmers do not use the fanning mill to clean out the light chaffy grains and weed seeds. They do not select their seed at all and after a time they say that their variety of wheat has "run out." Instead, the facts are that the wheat has been mixed with so many almost worthless wheats as to lose its identity, while the original wheat if purified might really be a better variety for the particular conditions than originally.

ORIGIN OF THE COMMON VARIETIES OF WHEAT.

It may be interesting to give the origin of a few of the better known American wheats. The Fultz wheat was originated in 1862 by Abraham Fultz of Mifflin County, Pa. He picked a few stray beardless heads out of a field of Lancaster wheat, which is bearded. He planted the grains from the selected heads that year and continued in this way until he had a considerable field of the new variety. This wheat is now being grown with good success in most of the eastern and central states and in several foreign countries.

In 1865, Mr. Garrett Clawson of Seneca county, New York, selected some of the best heads out of his field, the seed of which he increased during the next few years and thereby originated the White Clawson wheat.

Throughout the spring wheat districts of the northwest, there are a large number of Fife wheats forming the basis of the great wheat and flour production of that district. All of these are said to have been originated from a selection by Mr. David Fife, of Otonabee township, Ontario. A friend of his in Glasgow, Scotland, had obtained a small quantity of wheat from a cargo direct from Dantzic, Germany. Mr. Fife received it shortly before planting his spring wheat. As it proved to be a winter variety he was able to grow only three heads but he continued planting this wheat and distributing the product until now the Fife wheat is known throughout the country.

In Michigan we find several varieties that still carry the names of the originators. Among these are Betterley, Goings, Shepherd's Perfection, Eaton, Jones Longberry and Dawson's Golden Chaff.

PURIFYING AND TESTING VARIETIES.

At the Michigan Experiment Station thousands of individual plant selections are made. The seeds are at first planted so that it is absolutely known that each selection grew from a single seed. The best of these selections are planted in separate rows the next year. Here some of the undesirable lots are discarded before harvest. The remainder of the rows are threshed with that kind of care that allows not a single seed to get over into another lot.

The higher yielding of these wheats are planted in larger plots and as soon as possible they are planted in variety series. The plots in a variety series are usually one drill width (11 hoes) and long enough to make a one-twentieth acre plot. These long and narrow plots are placed side by side on as uniform land as is available. A three foot path extends between each two adjacent plots. The first and every fifth plot thereafter is planted with the same variety as a check on the variations in the soil. The remaining plots are planted to different varieties. By this means the relative yielding power of these pure strains is found. This work is repeated each year. The average of three or more years' results should give a fair comparison of the several varieties. The less promising varieties are discarded as soon as they are proven to be inferior. The aim in this work is to save the best varieties each year and test them out in comparison with new varieties and finally to develop better varieties for the benefit of the Michigan farmer. Seed of the best of these varieties is being sent out each year to representative

farmers who will keep the seed pure and sell seed to their neighbors. Through these co-operators the general farmer may expect finally to receive benefit from these pedigreed high producing wheats.

Thus the Experiment Station takes the ordinary commercial mixtures (called varieties) and if after some preliminary testing they are considered promising they are separated into several pure strains, each descending from single plants, and these are tested separately in the variety series. A variety that goes out to the farmer is not an original variety but the highest yielding pure strain found in one of them.

However, the yielding quality is not the only thing to be considered. The miller demands good milling wheats and the baker has a right to have good flour from which to make his bread. Thus a variety cannot be recommended simply because it is a high yielder but it must also be a

Fig. 2.—Series of 1/100 acre wheat plots in foreground, and 1/20 acre oat series in background. Mostly from individual plants of 1906. Crop of 1909.

good bread making wheat. The Experiment Station is now making milling and baking tests on the higher yielding wheats.

Finally the farmer must study the adaptability of new wheats to his conditions. As a rule the farmer should avoid sending off great distances for seed wheat unless it be for experimental purposes. The Experiment Stations generally find that varieties from other countries must be grown for two or three years in their new home before the yield can be relied upon. Even grain that comes from other states changes both in quality and yield and it is probable that grain changed from one kind of soil to another in the same neighborhood does not do as well the first year after the change as it would have done under its home conditions. The farmer who has been awake to his possibilities in obtaining the best variety for his farm and who has selected that seed carefully on his own soil has undoubtedly a much better variety for his own conditions than can ordinarily be obtained outside. A few years ago the Minnesota and

North Dakota Experiment Stations exchanged seed wheat of the same variety. It was a pure strain that had come originally from Minnesota. Each Experiment Station planted the home grown seed in a plot alongside of that obtained from the adjoining state. In each case the plot from the home grown seed produced the more. The experiment was repeated with the same results. On the average the home grown seed produced 2.5 bushels more per acre than the imported seed. This simply brings out the point that it is unsafe to get seed of a new variety of wheat for planting a general acreage unless the wheat has been tried under the same or similar conditions. It does not mean that wheats from the Experiment Stations or other sources should not be tried. A new variety from reliable sources may promise considerable in the way of increased yields, but should be used for the first time in a moderate way and in comparison with the home varieties.

WHAT FARMERS CAN DO TO IMPROVE THEIR WHEATS.

Farmers can keep their wheats from "running out." It is very important to keep a variety pure. A wheat said to be "run out" is really so badly mixed with low grade and poor yielding wheats (if not also weed seeds) as to lose its identity. Light wheat and weed seeds should always be cleaned out with a good fanning mill. Always remember that "like begets like," and a man can hope to harvest only what he sows.

Much of the work at the Experiment Station includes the isolation of pure strains and the testing of these to give the farmer only the best. The farmer can co-operate by keeping the wheats pure. The threshing machine brings grain from the neighboring fields and the first few sacks of grain threshed will be mixed with these other varieties. The farmer should always have his next year's seed in mind at threshing time. All he needs to do is to save his seed wheat after the machine has been running long enough to shake out all the foreign wheat. This wheat should then be stored separately for seed purposes.

If, however, a pure variety has been mixed, it can be purified with a little more work. Two or three hours should be spent just before the wheat is cut in gathering some of the best heads of the type of wheat that it is desired to raise. Half of a burlap sack full of such heads will give the farmer a good start. This sack should be hung up in a sheltered place, where it will have a free circulation of air and be away from the mice. When the heads are thoroughly dry, the wheat may be threshed by pounding the sack with a stick. Then after looking the fanning mill over to see that no other wheat is caught in the screens, run this small lot of wheat through. This pure wheat should be sown in a plot by itself being careful to keep it separate at threshing time the following season. It would pay to flail it out to make sure that it is not mixed with other wheats. This will provide enough seed to sow a good sized plot which can be threshed the next season with the ordinary thresher but the first two or three sacks of it must be set aside and the seed wheat saved after that.

WINTER KILLING.

The winters of 1909-1910 and 1911-1912 have enabled the Experiment Station to observe the wheats from the standpoint of endurance to cold and ice sheets, the past winter presenting especially favorable conditions

Fig. 3.—Portion of the 1912 wheat variety series showing an especially hardy plot.

Fig. 4.—The 1912 wheat nursery showing relative resistance to cold, among varieties.

for the comparison of the hardiness of the different varieties. In the variety series, where some varieties were almost entirely killed, others have survived fairly well. Nine varieties stand out so markedly as to attract attention and ten others are easily judged as superior to the check (Shepherd's Perfection) in power to resist cold.

In Fig. 3. is shown a portion of the 1912 variety series. The plots are long and narrow, as is also shown in Fig. 1. In the center of the cut may be seen Bearded Rock (97003) with a stand of 74.3%, spring of 1912. On the right is Shepherd's Perfection (61801) used as a check in the variety series. This variety had an average of 21% stand this spring. On the left is Bearded Mealy, with a stand of 19.4%.

In Fig. 4, is shown the nursery where new wheats are selected. The seeds are planted separately in hills 5 by 5 inches apart, that each plant may have the same chance and that the best plants may be found and selected as mothers of new strains. The plots are five feet wide and long enough to take care of 200 or 300 seeds. Each stake represents a plot. In the fall of 1911, a large number of foreign (Australian) varieties were planted here. This portion is shown to the left of the cut. These Australian wheats grew nicely last fall but were entirely winter killed. At the right may be seen some varieties of wheat that stood the winter in good condition. In the center of the cut also may be seen a variety (plot) that is a good stand. Many of the other varieties have been almost entirely winter killed. These are mostly varieties that farmers are growing in different parts of Michigan but had never been planted at the college before. A few of these varieties, however, came from other states. The effect of a hard winter like 1911-1912 is clearly shown.

Table 1. gives a comparison of some of the best wheats as to the resistance to cold and ice during the winter of 1911-1912. Some new wheats are included that are not mentioned in other tables of this bulletin because of their great resistance to unfavorable winter conditions.

TABLE 1.

Selection or accession number.	Names of varieties.	Description of varieties.			Percent.			
		Bearded or awnless.	Color of chaff.	Color and hardness of grain.	Winter resistance.	Patent flour.	Gluten in the patent flour.	Bread score.
60602	Early Windsor	Awnless	Red ..	Pearl (W)	53.8	61.9	9.65	82
60101	American Banner. .	Awnless.	Red	Pearl (W)	72.0	59.9	13.35	78
78605	Plymouth Rock ...	Awnless.	Red .	Pearl (W)	57.8	65.0	11.0	80
913502	Genesee Giant	Bearded	Red	Pearl (W)	31.7	53.1	12.85	90
61801	Shepherd's Perfection	Bearded .	Red	Common Red	21	56.2	13.65	92
97201	Shepherd's Perfection	Bearded	Red	Common Red	18.8	53.9	17.8	92
912102	From a cross	Bearded	White	Common Red	12.81	51.3	20.2	
912703	Craig's Favorite .	Awnless	White.	Common Red	82.2	58.7	21.8	.
97003	Bearded Rock. ..	Bearded.	White	Common Red	71.32	....	....	..
61101	Hungarian...... .	Bearded	White	Common Red	25.5	60.9	13.85	.
60201	Buda Pesth. .	Bearded	White	Soft Red	61.3	57.3	17.85	83
15	Berkley ...	Bearded.	White	Hard Red	74.5	66.7	11.8	91
61502	Mealy.... .	Awnless	White	Hard Red	23.8	70.0	15.6	83
913802	Harris	Bearded	White	Hard Red	75.2	61	12.95	.
925506	Stoner's Miracle	Bearded	White	Hard Red	67.5	61.2	12.75	..

PRODUCTION OF NEW VARIETIES BY CROSSING.

Several wheats were crossed in 1906 at the Michigan Experiment Station. Two of the resulting new wheats are mentioned in Table I, under numbers 912402 and 912703, of which the latter appears to be promising.

During the past six years a large number of other varieties have been closely studied. Three varieties, (viz. Genesee Giant, Shepherd's Perfection and Berkley) have been picked out as superior bread makers. Seven varieties in Table I produce above 60% patent flour and are therefore, good milling wheats. In considering winter hardiness, we find a half dozen wheats that have withstood the severe conditions of the past winter and are still good stands. Great differences among the varieties are also found in the yields, stiffness of straw and other characteristics.

Fig. 5.—Crossing wheats.

The best variety should combine a number of good traits. It should produce well, the straw should be stiff enough so as not to lodge in rainy seasons and it should be a winter hardy variety, moreover, it should be a good miller and its patent flour should produce good bread. Unfortunately, none of the Station wheats combine all of these qualities, therefore, a number of crosses were made during June, 1912. The traits entering into the parentage of any cross should unite in every possible combination in the second year (1914) and from among these it is hoped to select strains possessing better combinations of characters.

Among our highest yielding wheats, American Banner, (60101) has been selected as also being among the best resisters of winter conditions. This variety has been crossed with the best bread makers mentioned above and also three other wheats (viz. No's 912703, 913802 and 925306) that are also hardy and appear to have superior quality.

Berkley is our best variety considering the combination of winter

hardiness and high quality at the mill and in the oven. Its main defects are a weak straw and only a moderate yield. Besides American Banner, this wheat has been crossed with Early Windsor (60602), two strains of Shepherd's Perfection, (61801 and 95201), Plymouth Rock (78605) Genesee Giant, (913302), Bearded Rock (97003) Canadian Hybrid and Craig's Favorite (912703). These wheats all have stiffer straws than Berkley and include other desirable qualities.

Genesee Giant is our best bread maker among the pearl wheats. Besides the crosses with American Banner and Berkley, it has been crossed with Bearded Rock (97003), Harris (913802), Canadian Hybrid and Craig's Favorite (912703).

In all, twenty different crosses have been made during the month of June, making between 3,000 and 4,000 crossed flowers.

Fig. 5, shows the actual work of crossing in progress. First the flower must be emasculated, that is, the anthers containing the pollen or male element, must be removed and pollen for fertilizing the flowers is obtained from the other variety of the two wheats being crossed. The cut shows the application of pollen by means of a small brush to the emasculated flowers. The heads that are wrapped in white cloth are finished.

VARIETY TESTS.

During the past six years the Experiment Station has dealt with 126 varieties of wheat. These wheats have all been more or less mixed when they came to the Station, but the mixtures in many of them have been isolated and tested out alongside of the purified original sorts. There are, doubtless, many more varieties throughout the state that are promising for this breeding work and should be tested out in this way. However, many of Michigan's wheats are identical or nearly so, though known under different names. Again, a large number of varieties that are grown through the state are so low in milling quality as indicated by the softness of the grain, that it hardly seems worth while to add any more of them to the Station's list. When a farmer has a wheat that is harder than the average, and a good yielder on his farm, the Experiment Station would be glad to hear of it or receive a small sample as it may prove to excel others already obtained.

None of the softer white wheats have been listed in Table 11, as they are considered too poor in milling and baking qualities to be longer continued in the work. In the column headed color and hardiness of grain, pearl stands for a white wheat, which has somewhat of a pearly appearance, is fairly hard, and as a rule is a good milling wheat. Red, stands for red wheats, which are equal to the pearl type in hardness. The soft red wheats are softer than the pearl. The hard red types compare fairly well with the western hard winter wheats. All types contain a small portion of yellow berry.

Of the 300 selections which the Station has grown in 1912, most of those not represented in Table 11 have been tested in the larger plots for only one year, or are being grown in the small selection plots as yet. It will also be noticed that half of the varieties that are listed are not being continued in 1912. An indicates that the variety has been dropped. The reason for dropping these varieties has not been altogether the yield. The lowest yielders have been dropped. Then in the

middle class, those of poor quality have been dropped out of the work to make room for the more promising.

TABLE II.

Selection or accession numbers.	Names of varieties.	Description and yield of varieties tested.							
		Bearded or awnless.	Color of chaff.	Color and Hardness of grain.	Per cent.		Yield in bushels per acre.		
					Loose smut.	Lodged plants.	1911.	Average 2 yrs. 1910-11.	Average 3 yrs. 1909-11.
60602	Early Windsor	Awnless..	Red ...	Pearl	2	8	48.3	43.7	40.1
60101	American Banner	Awnless..	Red ...	Pearl	4	8	45.8	42.8	......
60501	*Early Ontario	Awnless..	White..	Pearl	1	7	46.3	41.9	37.8
60401	*Dawson's Golden Chaff.	Awnless..	Red....	Pearl	10	7	44.8	41.5	39.6
78605	Plymouth Rock	Awnless..	Red....	Pearl	1	6	38.0	40.0	......
8	Genesee Giant	Bearded..	Red....	Pearl	1	5	45.4	39.7	36.7
61801	Shepherd's Perfection	Bearded..	Red....	Red	1	9	45.9	39.3	39.2
61001	*Harvest Queen	Awnless..	White..	Pearl	1	4	40.7	38.1	......
78501	*Goings	Bearded..	Red....	Soft Red...	20	15	41.4	37.7	......
61101	Hungarian	Bearded..	Red ...	Red	0	6	39.7	37.1	......
61201	*Beechwood Hybrid	Awnless..	Mixed..	Red	3	3	41.5	36.9	33.5
60201	Buda Pesth	Bearded..	White..	Soft Red...	4	10	46.8	36.8	38.2
7	*European	Bearded..	White..	Red	8	10	43.3	35.3	34.1
15	Berkley	Bearded..	White..	Hard Red	0	10	40.2	35.1	34.1
61302	Mealy	Awnless..	White..	Hard Red..	3	4	42.4	34.9	33.6
60301	*Century	Awnless..	White..	Red	3	8	35.1	34.6	34.2
78508	*Awnless Goings	Awnless..	Red....	Red	1	14	32.0	33.7	......
28	*Turkey	Bearded..	White..	Hard Red	6	10	38.6	32.8	33.
40	*Silver Queen	Bearded..	White..	Red	2	14	32.1	31.4	31.6
41	*Babcock	Bearded..	White..	Red	3	9	35.1	31.2	31.7

*Dropped from work for 1912.

MILLING AND BAKING TESTS.

In the summer of 1910 the Station obtained an Allis-Chalmers mill with three pairs of rolls. Two pairs are corrugated and one is smooth. The coarsely corrugated rolls are used to take care of the first three breaks. The finer corrugated rolls finish the bran and shorts. The smooth rolls are used to complete the process of pulverizing the flour. The mill is fitted with a full set of bolting cloths so as to separate the products as desired.

In the winter of 1910-1911, samples of all the Station's wheats, then in the variety series, were ground into flour, only one grade being made from each wheat. Baking tests were made by the Domestic Science department of the Michigan Agricultural College, a loaf being made from each flour, using the same amount of flour, sugar, salt, and yeast in each case. The kneading, rising and baking were as uniform as possible and the breads differed only in the amount of water needed to make the dough of the right consistency. Two such tests were made at the college in the winter and the loaves exhibited at the State Corn Show. Two further tests were made at Columbus, Ohio, by the Domestic Science department of the Ohio State University and these were exhibited at the National Corn Exposition. Other tests were made at the college early in June, 1911, and the bread was exhibited at the National Association of Operative Millers in Detroit.

From the data secured from these baking tests, it has been possible to eliminate six of the varieties of only medium yielding quality because of inferior baking qualities.

TABLE III.

Results of Baking Tests on 1910 Crop.

Selection or accession numbers.	Names of varieties.	Michigan Agricultural College.			Ohio State University.			Average.		
		Weight of loaf grams.	Volume cc.	Score.	Weight of loaf grams.	Volume cc.	Score.	Weight of loaf grams.	Volume cc.	Score.
60602	Early Windsor	593	1873	81	592.6	2133	80	592.8	2003	82
60101	American Banner	589	1744	71	581.8	2020	83	585.4	1882	78
60501	*Early Ontario	598	1631	71	611.8	1796	62	604.9	1713	66
60401	*Dawson's Golden Chaff	578	1659	83	618.9	2096	65	598.4	1877	74
78605	Plymouth Rock	580	1688	82	597.1	2080	79	588.5	1884	80
8	Genesee Giant	582	1761	88	609.2	2285	92	595.6	2023	90
61801	Shepherd's Perfection	588	1654	91	587.2	2354	93	587.6	2004	92
61001	*Harvest Queen	588	1716	71	620.6	2180	75	604.3	1948	73
78501	*Goings	590	1706	85	621.1	2542	85	605.7	2024	85
61201	*Beechwood Hybrid	600	1716	69	611.0	2190	70	605.5	1953	69
60201	Buda Pesth	589	1829	80	603.9	2322	86	596.4	2075	83
7	European	586	1698	81	591.9	2300	84	588.9	1999	84
15	Berkley	588	1934	93	639.5	2392	95	613.7	2163	94
61302	Mealy	576	1915	84	641.2	2370	83	608.6	2147	83
60301	*Century	576	1759	78	612.4	2449	75	594.2	2104	76
78508	*Awnless Goings	572	1826	82	609.1	2310	91	590.5	2068	86
28	*Turkey	567	1695	92	609.1	2284	91	588.2	1989	91
10	*Silver Queen	576	1815	73	591.0	2170	75	583.5	1992	74
11	*Babcock	579	1788	84	613.8	2265	84	596.4	2026	84

*Dropped from work in 1912.

The extremely low yielders which are to be found at the bottom of Table III were dropped because of their low yield in the field. Others were dropped for other reasons, for instance, the Goings (78501) lodges easily and usually has a fifth to a sixth of the plants effected with the loose smut. The European has a weak straw and is not a hardy winter variety. The remainder of the discarded varieties are below 75% on bread score.

It will be noticed that the baking tests at M. A. C. and O. S. U. agree closely in score. Genesee Giant (Ac. No. 8), Shepherd's Perfection (61801), and Berkley (Ac. No. 15), are the best bread producing wheats among the medium and good yielders in the field. Turkey (Ac. No. 28) might have fallen into this class had it not been such a low yielder. The Berkley (Ac. No. 15), however, is a wheat of similar type but better in every way.

MILLING TESTS OF WHEATS HARVESTED IN 1911.

In February, 1912, milling tests were made with the different strains of wheat grown in 1911. The wheats were first scoured to remove the dust particles and the small hairs on the ends of the grains. In each case a ten pound sample was taken after scouring. Then it was tempered with the amount of moisture considered necessary to toughen the bran.

It was allowed to stand in a closed dish until it was no longer wet to the touch. Just before grinding, the sample was weighed again to determine the weight of water added. The yield of patent flour varied from 43% to 70%. The poorer varieties in this respect are not listed in Table IV. Nevertheless the Table shows great differences in the milling qualities of the different types of wheat.

TABLE IV.

Results of milling tests on 1911 wheats.

Selection or accession number.	Names of varieties.	Percentage of Products.						
		Scoured grain.	Moisture added.	Feed.	Flour.			Loss.
					Break.	Patent.	Tailings.	
60602	Early Windsor	100	0.8	26.7	4.0	61.9	4.1	1.1
60101	American Banner	100	1.2	30.3	7.8	59.9	2.7	0.5
60401	*Dawson's Golden Chaff	100	0.4	31.2	3.7	60.9	4.0	0.6
78605	Plymouth Rock	100	0.9	25.5	2.4	65.0	6.9	1.1
8	Genesee Giant	100	1.4	35.2	2.3	59.8	3.3	0.8
61801	Shepherd's Perfection	100	1.7	32.4	6.6	56.2	5.6	0.9
78501	*Goings	100	1.4	30.3	9.6	56.4	4.2	0.9
61101	Hungarian	100	0.8	29.1	1.8	60.9	5.3	0.7
60201	Buda Pesth	100	0.8	36.3	3.8	57.3	2.9	0.5
7	*European	100	1.8	33.1	3.5	58.6	5.8	0.8
15	Berkley	100	1.6	26.3	2.2	66.7	5.8	0.6
61302	Mealy	100	2.3	23.9	4.4	70.0	3.2	0.8
60301	*Century	100	1.0	32.5	2.5	61.4	4.0	0.6
28	*Turkey	100	0.8	28.1	6.0	62.5	3.7	0.5

*Dropped from work in 1912. Half of those marked with an * Tables II and III are also omitted here.

TABLE V.

Relation of hardiness to milling quality.

Classes of Wheats.	No. of wheats tested.	Type.	Percentage of Products.						
			Flour.						
			Scoured grain.	Moisture added.	Feed.	Break.	Patent.	Tailings.	Loss.
Hard red wheats	16	HR.	100	1.5	26.1	4.2	66.4	4.2	.6
Good quality pearl	15	W.	100	0.9	29.8	4.0	62.1	4.2	.8
Ordinary red	24	R.	100	1.3	32.3	4.7	58.2	5.3	.8
Soft red wheat	6	SR.	100	1.1	32.6	6.7	56.9	4.3	.6

Each of the lines in Table V show the average of the milling tests on the type of wheat in question. These are arranged in the order of the production of patent flour. If the soft white wheats had been included, they doubtless would have produced the smallest average per cent of patent flour. The production of feed and also break flour decreased as the patent flour increased. These data indicate that the pearl wheats are

better in milling qualities than the ordinary red wheats although the latter are considered to be better bread producers. The hard red class of wheats is the best of all in milling qualities. There are, however, great differences between the varieties even in the same class. The Mealy, for instance, is an odd variety in the hard red class of wheats. It is a low yielder in the field because it is easily attacked by insects. It shows an exceptional yield of patent flour at the mill but the flour is dark in color and produces a poor, dark colored bread.

TABLE VI.

Analyses of wheats harvested in 1911.

Selection or accession numbers.	Percentage of constitutents.						
	Scoured wheat.	Protein N X 5.7	Starches sugars and other carbo-hydrates.	Ether extract or fat.	Crude fiber.	Ash.	Moisture.
60602	100	10.91	73.27	2.57	2.50	1.71	8.98
60101	100	11.80	73.03	2.60	2.40	1.72	8.45
60401	100	12.43	71.11	2.76	2.90	1.86	8.61
78605	100	12.48	71.57	1.95	2.75	1.74	9.51
8	100	12.48	71.48	2.36	2.85	1.91	8.92
61801	100	13.22	71.22	2.45	2.57	1.95	8.59
78501	100	14.25	70.11	2.09	2.79	1.73	9.03
61301	100	12.88	71.50	2.35	2.36	1.92	8.99
60201	100	14.53	68.91	2.45	2.58	1.81	9.69
7	100	13.79	70.17	2.27	2.72	1.91	9.14
15	100	14.53	70.31	2.38	2.42	1.70	8.66
61302	100	13.40	70.32	2.50	2.78	1.80	9.20
60301	100	13.22	70.71	2.33	2.57	1.93	9.24
28	100	11.97	72.83	2.31	2.21	1.69	8.96

Table VI. shows the chemical analyses made on these wheats (Crop of 1911) by the Chemistry division of the Experiment Station.

SUMMARY.

1. The wheats grown throughout the state include many varieties which are poorly adapted to the conditions under which they are grown as shown by the low yield, poor bread making qualities, lack of winter hardiness, tendency to lodge, etc.

2. Pure varieties have been originated at the Experiment Station from single plants, found, as mixtures in old varieties. These types may have been carried accidentally from other fields or may have been produced from accidental crossing.

3. At the Experiment Station hundreds of varieties or strains have been isolated and tested for yield, milling and baking qualities, hardiness, etc., with the idea of finding the best all round wheats for sending out to the farmers of the state.

4. Finding no existing variety with a high excellence in all the characteristics, the Experiment Station has attempted to produce better combinations of characters by means of crossing of the better types.

5. In order to make the immense amount of work done at the Experiment Station in the breeding of wheats of much practical value to the farmers of the state, these improved wheats must be thoroughly tested in the different sections to learn their adaptability to the different

conditions. Plans have been perfected for the testing of these wheats on the farm and to increase in the hands of the farmer those varieties that prove to be valuable.

6. The farmer can keep his wheat from "running out" by use of a fanning mill, by the proper care in threshing and by occasional selection of a few heads at harvest time to be planted in a seed plot.

7. A large number of the varieties may be classed as soft white and soft red wheats; they are apt to be yellow, yellow spotted or bleached in color.

8. The best varieties among the white wheats have a clear pearly appearance. The pearl wheats are apt to be good millers, usually better than the ordinary red wheats.

9. The ordinary red wheats usually produce better bread than the pearl wheats.

10. The best milling wheats and usually the best bread producers are found in the hard red wheats. These wheats, however, make only a medium yield per acre in this state.

11. The best resisters to the winter conditions of 1911-1912 are the American Banner, Craig's Favorite, Bearded Rock, Berkley, Harris, Stoner's Miracle, Gypsy, Ohio 5309, White Eldorado, Awnless Berkley and Canadian Hybred. The first is a pearl wheat, the next two are common red wheats and the next three are hard red wheats. The Gypsy and the Ohio 5309 are soft red wheats. The White Eldorado is a spotted pearl and the last two are high grade red wheats.

12. Among these better winter resisters, American Banner and Berkley are the only ones that have been tested long enough to report results. Some of the others may yet prove to be valuable wheats for Michigan. The American Banner is a high yielding wheat of medium good quality. It is the best white wheat that the Experiment Station can recommend to date. The Berkley is the best miller and best bread maker but has a weak straw and is only fair in yield.

13. The Shepherd's Perfection has been the Station's highest yielding red wheat and is also among the best in bread making qualities but it does not take a high rank in winter resistance. The winter conditions during the past winter have, however, been more severe than have been experienced since 1885 and it may be said in favor of this wheat that it has survived the winter in good condition during all the other seasons it has been tested. While an attempt will be made to combine the good qualities of this wheat with the winter resistance of some of the other wheats, this variety is the best all-round red wheat for general recommendation to the farmers thus far discovered by the Experiment Station.

FERTILIZER ANALYSES.

Bulletin No. 269.

ANDREW J. PATTEN, WM. C. MARTI AND ARAO ITANO.

The inspection and analyses of the commercial fertilizers offered for sale in Michigan are made under authority of an act of the Legislature approved March 10, 1885. The full text of the law is again printed since many inquiries are continually received concerning it.

SECTION 1. *The People of the State of Michigan enact*, That any person or persons who shall sell or offer for sale in this State any commercial fertilizer, the retail price of which exceeds ten dollars per ton, shall affix on the outside of every package containing such fertilizer a plainly printed certificate, stating the number of net pounds therein; the name or trade mark under which such article is sold; the name of the manufacturer; the place of manufacture, and a chemical analysis, stating the percentage of nitrogen in an available form; of potash soluble in water and of phosphoric acid in available form (soluble or reverted) and the insoluble phosphoric acid.

SEC. 2. Before any commercial fertilizer is sold or offered for sale, the manufacturer, importer or party who causes it to be sold or offered for sale within this State, shall file with the secretary of the State Board of Agriculture a certified copy of the analysis and certificate referred to in section one, and shall also deposit with said secretary a sealed glass jar containing not less than two pounds of such fertilizer, with an affidavit that it is a fair sample of the article thus to be sold or offered for sale.

SEC. 3. The manufacturer, importer, or agent of any commercial fertilizer, the retail price of which exceeds ten dollars per ton as aforesaid, shall pay annually to the secretary of the State Board of Agriculture, on or before the first day of May, a license fee of twenty dollars for each and every brand of fertilizer he offers for sale in this State: Provided, That whenever the manufacturer or importer shall have paid this license fee his agents shall not be required to do so.

SEC. 4. All such analyses of commercial fertilizers required by this act shall be made under the direction of the State Board of Agriculture and paid for out of the funds arising from the license fees provided for in section three. At least one analysis of each fertilizer shall be made annually.

SEC. 5. The secretary of the State Board of Agriculture shall publish in his annual report a correct statement of all analyses made and certificates filed in his office; together with a statement of all moneys received for license fees, and expended for analysis. Any surplus from license fees remaining on hand at the close of the fiscal year shall be placed to the credit of the experimental fund of said board.

SEC. 6. Any person or persons who shall sell or offer for sale any commercial fertilizer in this State without first complying with the

provisions of sections one, two, and three of this act, or who shall attach or cause to be attached to any such package or fertilizer an analysis stating that it contains a larger percentage of any one or more of the constituents or ingredients named in section one of this act than it really does contain shall, upon conviction thereof, be fined not less than one hundred dollars for the first offense, and not less than three hundred dollars for every subsequent offense, and the offender shall also be liable for damages sustained by the purchaser of such fertilizer on account of such misrepresentation.

SEC. 7. The State Board of Agriculture by any duly authorized agent is hereby authorized to select from any package of commercial fertilizer exposed for sale in this State, a quantity, not exceeding two pounds, for a sample, such sample to be used for the purposes of an official analysis and for comparison with the certificate filed with the secretary of the State Board of Agriculture and with the certificate affixed to the package on sale.

SEC. 8. All suits for the recovery of fines under the provisions of this act shall be brought under the direction of the State Board of Agriculture.

LICENSED BRANDS.

Twenty-seven manufacturers and fertilizer companies have licensed 267 distinct brands for sale in the State during the season of 1912. The brands appearing in the following tables of analyses, and no others, can be legally sold.

Parties manufacturing or importing fertilizers for their own use and not for sale are not affected by the restrictions of the law.

COLLECTION OF SAMPLES.

The sampling agents of the Station, during the months of April, May and June, drew 526 samples from dealers' stocks representing 232 different brands. The failure to get samples of 35 brands is due to the fact that many of them are sold only in the fall, then, too, a few companies sell direct to the consumer through the Grange and other organizations and consequently it is only by chance that samples of such goods are obtained. If persons ordering goods in this way wish to have them inspected they will protect themselves and at the same time confer a favor on this department by notifying us, and upon the arrival of the goods an inspector will be sent to draw samples.

It is the desire of this department to make the inspection as complete as possible, and any information to further this end from dealer or consumer will be greatly appreciated. In all cases of failure to find a brand on the market, the analysis was made on the manufacturer's sample as indicated in the tables of analyses.

RESULTS OF INSPECTION.

A study of the tables of analyses shows that, of the 298 samples analyzed, representing 267 brands, 27 (9%) are below guarantee* in one or more constituents. Ten (3.3%) are below guarantee in nitrogen, 6 (2%) are below guarantee in available phosphoric acid, 1 (0.4%) is below guarantee in total phosphoric acid and 13 (4%) are below

guarantee in potash. Two (0.7%) are below guarantee in nitrogen and potash, 1 (0.3%) in potash and available phosphoric acid.

While there are, as stated above, 27 samples falling below guarantee in one or more constituents, there is, however, only 1 (0.3%) that is more than 75 cents per ton below its guaranteed commercial value. This is a very satisfactory showing.

SCHEDULE OF TRADE VALUES.

In accordance with the custom adopted and followed in previous years, the following schedule of prices for determining the commercial valuation of a fertilizer is published:

Nitrogen	17.8c	per pound
Potash soluble in water	4½c	" "
Available phosphoric acid	5c	" "
Total phosphoric acid in bone	4c	" "
Insoluble phosphoric acid in fertilizers containing nitrogen	2c	" "

In fertilizers containing no nitrogen no value is given to insoluble phosphoric acid. The valuation of a fertilizer is determined as follows: The percentage or pounds per hundred of each ingredient (nitrogen, available phosphoric acid, insoluble phosphoric acid and potash) is multiplied by 20, giving the number of pounds of each ingredient in a ton. These figures are then multiplied by their respective pound prices.

In the last column of the table of analyses headed "Valuation" is given the commercial valuation of the samples, as guaranteed and as found, based upon the prices quoted above.

In calculating the valuations we have assumed that the sources of the various ingredients have been the same in all cases, which of course is not true and also unfair to the manufacturer using only high grade materials, as it places the manufacturer who uses low grade goods on the same level. Consequently it should be clearly understood that the Station valuation does not represent the proper retail cost of the fertilizer at the point of consumption. It does, however, represent the cash cost, at the larger fertilizer centers of the middle west, of an amount of nitrogen, available phosphoric acid and potash in unmixed, standard raw materials of good quality, corresponding to the amounts found in one ton of the fertilizer in question.

The difference between the selling price and the Station valuation is represented by the cost of storing, grinding, bagging, hauling and freighting the goods, commissions to agents and dealers, bad debts, depreciation of machinery, interest on investment, etc. The difference between the selling price and Station valuation should not exceed 35 or 40 per cent. The Station valuations are useful to show whether a fertilizer is worth its guaranteed money value and purchasers will often find them of advantage in comparing the relative values of similar brands offered by different manufacturers. The commercial valuation of a fertilizer bears no relation to its agricultural value. The agricultural value is measured by the increased yield of crop due to its use.

The great difference in fertilizers from the commercial as well as from

*A shortage of more than 0.10 per cent of nitrogen of more than 0.20 per cent of available phosphoric acid or potash is considered below guarantee.

the agricultural standpoint lies in the quality of the materials supplying the nitrogen. The sources of phosphoric acid and potash, available for fertilizer use, are few and they are, fortunately, of good quality. On the other hand, the sources of nitrogen available for the fertilizer trade are many and of very variable quality. Since the nitrogen is much more costly than either the phosphoric acid or potash it will be readily seen that the quality of the nitrogen supplied in the mixed fertilizer becomes an important one.

If it were possible to detect the materials used in compounding a fertilizer it would then be a simple matter to determine its worth but the process of manufacture is such as to make the identity of the materials very difficult, if not impossible. Consequently, the only safe advice, at the present time, that can be given to guide one in purchasing, is to always buy high grade fertilizers, because in compounding such fertilizers only high grade materials can be used. On the other hand low grade materials are quite generally used in mixing low grade fertilizers.

A comparison of the cost of plant food in the high and low grade fertilizers was published in Bulletin 252, which was distinctly in favor of the high grade fertilizer.

Following are the names of the parties from whose stocks samples were drawn:

Adair—C. P. Lipke.

Addison—Louis & Vanile.

Adrian—J. C. Van Doren, J. E. Bennett, H. Wellintz.

Alma—J. M. Montigel.

Amadore—Wm. Anderson.

Applegate—Byron Kelly, Farmers Grain & Hay Co.

Ashley—A. M. Derry & Son, Rockefellow Grain Co.

Azalia—E. F. Cowper.

Bad Axe—S. H. Pangborn, Jacob Sparling, Slack Bros.

Bankers—Wm. Cole.

Battle Creek—Robert Binder Estate.

Bay City—F. C. Goodeyne, Mohr Hardware Co., Presley & Layer, Jenison Hardware Co., Bay City Hardware & Implement Co.

Bay Port—A. Morse.

Belleville—A. Jackson, Stephen Pearl.

Benton Harbor—Cutler & Downing, B. M. Nowlen & Co.

Birmingham—Smith Bros., H. B. Parks.

Blissfield—W. A. Worthey, J. A. Mominee, Joe Rouget, F. L. Ganum, W. J. Uckele.

Brown City—J. H. Linck.

Butternut—Butternut Bean & Grain Co.

Camden—Geo. L. Tanner.

Capac—Lang Bros., L. R. Glassford.

Carlton—L. J. Guiermann.

Charlotte—Hertell & Martin.

Clayton—E. H. Hutchins.

Clinton—W. D. Vantuyl.

Coldwater—A. J. Fiske, S. I. Treat & Son, E. Dunton.

Coloma—G. R. Brown, I. G. Leedy, Coloma Hardware Co.

Coopersville—Laug Bros.

Covert—J. R. Spealman.

Croswell—W. Quale, Croswell Elevator Co., Sandusky Grain Co.
Davison—E. G. Post, J. J. Berry, Hammond & Hathaway.
Dearborn—S. Baldwin Estate, Chas. A. Kendt.
Deckerville—J. C. Merriman, Cowan & Binkle.
Deerfield—Frank Timmins.
Detroit—Lohrman Seed Co.
Dowagiac—Belton & Burch.
Dundee—Michigan Milling Co., Dundee Mercantile Co., O. Silley.
Durand—Durand Implement Co.
East Saugatuck—Vos. Reinerd.
Eaton Rapids—Frank E. Ford.
Farmington—V. G. Lockwood.
Flint—J. P. Burroughs & Son.
Galien—Swank & Dempsey.
Grand Haven—Speidel & Swartz.
Grand Rapids—Wm. Groen & Son, Grand Rapids Glue Co., Brown Seed Co., Jones Seed Co.
Greenville—E. B. Slawson.
Hand—J. H. Lang.
Hartford—H. L. Gleason.
Hastings—Edmonds Bros.
Hillsdale—T. H. Eddy & Co.
Holland—Mulder & Co., Henry Siersma, H. W. Harrington, John Meeswesner.
Howell—A. F. Bennett.
Hudson—W. D. Rhead, Jack Dilton, Atherton & Garling.
Hudsonville—Fred Yonker, C. Spoolman, B. T. Hughes.
Hunters Creek—M. Caley.
Ida—J. E. Schnell, N. A. Weipert & Sons, Ida Hardware Co.
Imlay City—B. Churchill.
Inkster—Geo. C. Walker, McNutt & Moore.
Ithaca—I. N. Cowdry, G. J. Coleman & Son, Ithaca Roller Mills, S. J. McWilliams.
Jackson—James Boland & Co., Isbell Seed Co.
Kibbie—J. H. Myers & Son.
Kingsland—Walter Halifax.
Lake Odessa—Claude Carpenter.
Lakeview—Rossman Bros.
Lambs—Farmers Elevator Co.
Lansing—Young Bros. & Daley, McKim & Longstreet, Dubois & Hughes, Briggs & Co.
Lapeer—Turnbull Elevator Co.
LaSalle—John S. Heck.
Lawton—C. Dunham.
Lenawee Junction—D. F. Rockwell.
Lenox—Farmers Elevator Co.
Leslie—Darling & Freeman.
Lulu—Miles Elwood.
Manchester—Lonier & Hoffer.
Mason—John Bullen, A. J. Leonard, R. A. Osborn, J. E. Taylor, Dan Sears.
Mayville—Phelps Bros., A. E. Hollenbeck.

Memphis—F. G. Coburn, Day & McCall.
Middleville—E. J. McNaughton.
Milan—A. G. Forsyth & Co.
Monroe—Geckle & Martin, Monroe Hardware Co.
Montgomery—George R. Pierce.
Mt. Clemens—Wolf Bros., Clark & Hall.
Muskegon—J. Stegink.
New Boston—R. E. Krause.
New Buffalo—Siegmund Bros.
Novi—W. E. Erwin.
Nunica—J. D. Pickett, E. W. Hass.
Petersburg—H. Logan & Son, C. N. Wadsworth, E. T. Thompson, J. West.
Pewamo—M. J. Simon, Jas. W. Steel.
Pigeon—E. Paul, Daepker Bros.
Plymouth—W. S. Burch, James Gates, J. D. McLaren, G. C. Ravilier.
Pontiac—E. Howland & Sons.
Port Huron—McMorran Milling Co.
Portland—A. C. Barnard.
Quincy—Wm. A. Lott, Geo. Snyder, J. N. Boyer.
Reading—A. L. Lane, Kellog & Young, Jackson & Field, W. M. Cahow.
Redford—C. A. Lasher, Westlake Bros.
Romeo—Bradley & Chubb, Romeo Milling & Elevator Co.
Romulus—Dick Mewsom.
Royal Oak—J. M. Lawson.
Ruth—J. F. Schroeder, Bad Axe Grain Co., S. G. Gentner.
Saginaw—H. W. Carr & Co., Jerome Bros.
St. Clair—Recor & Smith, John Mau.
St. Johns—John Wallace Sons Co.
St. Louis—William G. Gibbs, St. Louis Hardware Co.
Sebewaing—John Rummel, E. Grasmann, Myers Reidel & Co., J. C. Liken & Co., —— Krohn.
Swartz Creek—A. C. Goodyear.
Tecumseh—Clayton & Son, J. McIntyre.
Temperance—R. W. Brunt.
Ubly—Chas. Ewing, D. H. Pierce.
Union City—A. D. Marsh, E. Worten.
Vassar—Farmers Elevator Co.
Vermontville—E. F. Tubbs, C. C. Hallenbeck, Vermontville Lumber Co.
Verona Mills—Geo. H. Whitham.
Vriesland—T. W. VanHaitsma.
Wayne—E. H. Langworthy, Wayne Milling & Produce Co.
Washington—J. F. Dernberger, R. Teeter.
White Pigeon—G. D. Grossman.
Woodland—J. S. Reisinger.
Wyandotte—F. C. Koch, Fred Busch.
Ypsilanti—O. E. Thompson & Son, M. Dawson, J. A. Minnich, I. B. Lefurge.
Zeeland—Van Dyke & Co., Vanhoven & Vereeke Co., Nykamp Bros.

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	American Agricultural Chemical Company, Detroit, Mich.		
3027	Banner Dissolved Bone	Detroit	Claimed... Found.....
3346	Banner Bone With Potash	Manufacturer's sample	Claimed.... Found.....
3228	Beet Fertilizer	Vassar	Claimed.... Found.....
3028	Double 10 Fertilizer	Bankers	Claimed.... Found.....
3029	Fine Ground Bone	Detroit	Claimed.... Found ...
3030	High Grade Bone and Potash	Lenawee Jct	Claimed.... Found.....
3310	High Grade Garden and Vegetable Fertilizer	Belleville	Claimed.... Found.....
3033	Maine Potato Formula	Ypsilanti	Claimed ... Found. ..
3031	M. & L. Special Manure	Reading	Claimed.... Found. ..
3196	Michigan Bean Grower	Vassar	Claimed.... Found. ..
3240	Michigan 10 per cent Potash	Eaton Rapids	Claimed.... Found ....
3037	Muriate of Potash	Detroit	Claimed.... Found ..
3038	Nitrate of Soda	Detroit	Claimed.... Found ..
3035	New York State Special	Montgomery	Claimed ... Found ..

1912, expressed in parts per one hundred.

Nitrogen.	Phosphoric Acid. Total.	Phosphoric Acid. Insoluble.	Phosphoric Acid. Available.	Potash.	Valuation.
....	 38	.... 3 40	34 31 60	....	$34 00 31 60
....	20 22.67	.... 3 73	24 26 30	4 4.44	23 60 26 67
1 23 1 40	11 12.55	.... 2.82	9 9.73	2 2.30	15 98 17 91
....	12 14.35	.... 2 30	10 12.05	10 9.90	19 00 20 96
2 47 2.92	20 18.50	....	....	....	24 80 25 19
....	12 13.25	.... 1 87	10 11.38	5 5.40	14 50 16 24
1.65 1.80	10 10.60	.... 0.35	8 10.25	5 5.15	19 17 21 44
1 65 1.88	10 10.68	.... 1 30	8 9.38	10 11 67	23 67 27 10
2.47 2.72	10 11.55	.... 1.82	8 9.73	6 6.47	23 00 25 97
1 65 1.68	10 10.60	.... 1.55	8 9.05	3 3 01	17 37 18 36
0.82 0 98	7 6.90	.... 0 70	5 6 20	10 10.19	17 72 19 14
....	....	....	....	49 52 25	44 10 47 03
15 15.70	....	....	....	....	53 40 55 89
0 82 1.23	10 11 50	.... 2.80	8 8.70	3 3.93	14 42 17 74

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	American Agricultural Chemical Co.—*Con.*		
3036	Special Pea and Truck Grower	Wayne	Claimed
			Found
3197	Bradley's Acid Posphate	Covert	Claimed
			Found
3263	Bradley's Alkaline Bone Potash	Amadore	Claimed
			Found
3198	Bradley's B. D. Sea Fowl Guano	Hudsonville	Claimed
			Found
3039	Bradley's Dissolved Bone and Potash	Monroe	Claimed
			Found
3173	Bradley's Niagara Phosphate	Ruth	Claimed
			Found
3200	Bradley's Soluble Dissolved Bone	Hudsonville	Claimed
			Found
3201	Bradley's Special Potash Fertilizer	Covert	Claimed
			Found
3241	Crocker's Ammoniated Wheat and Corn Phosphate	Farmington	Claimed
			Found
3040	Crocker's Dissolved Bone and Potash	Montgomery	Claimed
			Found
3041	Crocker's General Crop Phosphate	Lenawee Jct	Claimed
			Found
3042	Crocker's New Rival Ammoniated Superphosphate	Belleville	Claimed
			Found
3043	Crocker's Universal Grain Grower	Belleville	Claimed
			Found
3045	Homestead Bean Fertilizer	Quincy	Claimed
			Found
3311	Homestead Bean Fertilizer	Middleville	Claimed
			Found

1912, expressed in parts per one hundred.

Nitrogen.	Phosphoric Acid. Total.	Phosphoric Acid. Insoluble.	Phosphoric Acid. Available.	Potash.	Valuation.
2.17 2.71	11 12.20	...... 1.77	9 10.13	2 2.50	$20.40 23.04
....	12 13.25	 2.80	10 10.45		10.00 10.45
....	12 13.90	...... 1.35	10 12.55	2 2.28	11.80 11.60
2.06 2.22	10 11.50	...... 1.62	8 9.88	1.50 1.71	17.49 20.00
1.03 1.08	10 11.93	.... 1.72	8 10.21	2 2.16	14.27 16.96
0.82 1.01	9 10.10	.... 1.62	7 8.78	1 1.46	11.62 11.44
....	16 18.50	.... 2.70	14 15.80	....	14.00 15.80
0.82 0.93	10 10.95	.... 1.67	8 9.28	3 3.39	14.42 16.31
2.06 2.22	10 10.75	.... 1.07	8 9.68	1.50 1.93	17.49 19.75
....	12 12.73	.... 2.12	10 10.61	2 2.15	11.80 12.82
0.82 1.15	9 10.35	.... 2.10	7 8.25	1 1.10	11.62 11.45
1.23 1.45	11 12.35	.... 2.15	9 10.20	2 2.42	15.98 18.40
0.82 1.01	10 11.45	.... 1.37	8 10.08	2 2.38	13.52 16.37
1.65 1.74	10 10.75	.... 1.00	8 9.75	3 2.97	17.37 19.02
1.65 2.12	10 11.25	.... 0.64	8 10.61	3 3.26	17.37 21.35

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	American Agricultural Chemical Co.—Con.		
3242	Homestead Best Potato Fertilizer	Union City	Claimed.... Found.....
3046	Homestead Bone Black Fertilizer	Middleville	Claimed.... Found.....
3047	Homestead High Grade Garden and Vegetable Fertilizer.	Hastings	Claimed.... Found ....
3032	Homestead High Potash Phosphate	Woodland	Claimed.... Found ...
3048	Homestead M. and I. Fertilizer	Middleville	Claimed.... Found ....
3277	Homestead Pea and Truck Fertilizer	Manufacturer's sample	Claimed.... Found ...
3229	Homestead Special Beet Fertilizer	Pigeon	Claimed.... Found ....
3049	Homestead Sugar Beet Fertilizer	Royal Oak	Claimed.... Found ....
3050	Homestead 10 per cent Potash Manure	Hastings	Claimed.... Found ..
3051	Homestead Ten Ten Special Compound	Reading	Claimed ... Found ...
3044	A-1 Potash Fertilizer	Hastings	Claimed .. Found ..
3052	Red Line Complete Manure	Redford	Claimed ... Found
3202	Red Line Phosphate	Vriesland	Claimed .. Found ..
3053	Red Line Phosphate With Potash	Woodland	Claimed.... Found ...
3203	Wolverine Phosphate	Holland	Claimed .. Found ....

1912, expressed in parts per one hundred.

Nitrogen.	Phosphoric Acid. Total.	Phosphoric Acid. Insoluble.	Phosphoric Acid. Available.	Potash	Valuation.
1.65 1.73	10 10.15	.... 0.92	8 9.23	10 11.11	$23.67 25.79
2.06 2.29	10 11.60	.... 2.87	8 8.73	1.50 1.95	17.49 19.80
1.65 1.80	10 10.55	.... 1.35	8 9.20	5 5.18	19.17 20.81
....	12 13.75	.... 1.95	10 11.80	5 5.36	11.50 16.62
2.17 2.54	10 11.55	.... 1.47	8 10.08	6 6.39	23.00 25.47
2.17 2.82	11 12.50	.... 1.48	9 11.02	2 2.63	20.40 24.02
1.65 1.84	10 10.90	.... 1.25	8 9.65	5 5.46	19.17 21.61
1.23 1.52	11 13.30	.... 2.62	9 10.74	2 2.24	15.98 19.23
0.82 1.00	7 7.80	.... 1.27	5 6.53	10 10.80	17.72 20.32
....	12 13.55	.... 2.85	10 10.70	10 10.14	19.00 19.83
0.82 1.02	10 11.20	.... 2.00	8 9.20	3 3.19	14.42 16.50
0.82 1.28	9 11.20	.... 2.17	7 9.03	1 1.30	11.62 15.63
....	16 17.25	.... 2.95	14 14.30	....	14.00 14.30
....	12 13.30	.... 2.40	10 10.90	2 2.07	11.80 12.76
....	12 12.95	.... 2.62	10 10.33	....	10.00 10.33

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	American Agricultural Chemical Co.—Con.		
3243	Niagara Dissolved Bone and Potash	Adair	Claimed Found
3174	Niagara Grain and Grass Grower	Romeo	Claimed Found
3244	Niagara Potato and Vegetable Fertilizer	La Salle	Claimed Found
3175	Niagara Wheat and Corn Producer	Washington	Claimed Found
3278	Horse Shoe Acidulated Bone and Potash	Manufacturer's sample	Claimed Found
3230	Horse Shoe Animal Bone Manure	Lapeer	Claimed Found
3054	Horse Shoe Bean Special	Blissfield	Claimed Found
3055	Horse Shoe Bone and Potash	Ida	Claimed Found
3056	Horse Shoe Corn and Wheat Grower	Adrian	Claimed Found
3057	Horse Shoe Garden City Superphosphate	Wayne	Claimed Found
3204	Horse Shoe Half Potash Fertilizer	Brown City	Claimed Found
3312	Horse Shoe Half Potash Fertilizer	Greenville	Claimed Found
3058	Horse Shoe High Grade Vegetable Fertilizer	Blissfield	Claimed Found
3059	Horse Shoe Maine Potato Fertilizer	Wayne	Claimed Found
3060	Horse Shoe Potash Manure	Adrian	Claimed Found

1912, expressed in parts per one hundred.—Con.

Nitrogen.	Phosphoric Acid.			Potash.	Valuation.
	Total.	Insoluble.	Available.		
....	12 12.70	.... 2.22	10 10.48	2 2.20	$11.80 12.16
0.82 0.97	9 10.35	.... 1.65	7 8.70	1 1.29	11.62 13.98
2.06 2.13	10 10.65	.... 1.10	8 9.55	3 3.17	18.83 20.69
1.23 1.10	11 13.00	.... 1.90	9 11.10	2 2.32	15.98 18.93
0.82 1.11	12 15.20	.... 3.17	10 12.03	1 1.30	14.62 18.42
0.82 0.95	9 12.70	.... 1.70	7 11.00	1 1.26	11.62 16.19
1.65 1.81	10 12.10	.... 2.75	8 9.35	3 3.90	17.37 20.40
....	12 13.30	.... 2.40	10 10.90	2 2.00	11.80 12.70
1.65 2.02	10 12.35	.... 2.32	8 10.03	2 2.31	16.47 20.23
2.06 2.32	10 12.35	.... 2.67	8 9.68	1.50 1.66	17.49 20.50
....	12 13.00	.... 1.30	10 11.70	10 9.12	19.00 19.91
....	12 12.95	.... 1.48	10 11.47	10 10.30	19.00 20.74
1.65 1.95	10 12.00	.... 2.25	8 9.75	5 5.26	19.17 22.32
1.65 1.91	10 11.35	.... 1.47	8 9.88	10 10.99	23.67 27.16
0.82 1.15	10 11.43	.... 1.75	8 9.68	3 3.13	14.42 17.29

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	American Agricultural Chemical Co.—Con.		
3176	Horse Shoe Quick Acting Phosphate	Ubly	Claimed Found
3061	Horse Shoe Special Onion and Vegetable Manure	Mason	Claimed Found
3062	Horse Shoe Square Deal Phosphate	Ida	Claimed Found
3063	Horse Shoe Sugar Beet Fertilizer	Mason	Claimed Found
3205	Horse Shoe 3-8-6 Fertilizer	Brown City	Claimed Found
3064	Horse Shoe 10-5 Potash Manure	Wayne	Claimed Found
3065	Boar's Head Corn and Wheat Grower	Wyandotte	Claimed Found
3177	Boar's Head Dissolved Phosphate and Potash	Ruth	Claimed Found
3066	Boar's Head Faultless Grain Grower	Wyandotte	Claimed Found
3313	Boar's Head Faultless Grain Grower	Ruth	Claimed Found
3276	Boar's Head Gilt Edge Phosphate	Kingsland	Claimed Found
3067	Boar's Head High Grade Vegetable Fertilizer	Wyandotte	Claimed Found
3206	Boar's Head Potash Phosphate Fertilizer	Applegate	Claimed Found
3311	Boar's Head Potash Phosphate Fertilizer	Alma	Claimed Found
3207	Boar's Head Soluble Phosphate	Applegate	Claimed Found

1912, expressed in parts per one hundred.—Con.

Nitrogen.	Phosphoric Acid. Total.	Phosphoric Acid. Insoluble.	Phosphoric Acid. Available.	Potash.	Valuation
....	12 13.15	.... 2.32	10 11.13	....	$10.00 11.13
0.82 1.05	7 7.75	.... 1.70	5 6.05	10 10.82	17.72 20.21
....	16 18.20	.... 3.52	11 14.68	....	14.00 14.68
1.23 1.54	11 13.00	.... 2.80	9 10.20	2.00 2.05	15.98 18.65
2.47 2.49	10 10.90	.... 1.00	8 9.90	6 6.17	23.00 21.71
....	12 12.85	.... 2.15	10 10.70	5 5.57	11.50 15.71
1.65 1.77	10 11.70	.... 1.75	8 9.95	2 2.36	16.47 19.07
....	12 13.50	.... 2.47	10 11.03	2 2.41	11.80 13.20
0.82 1.04	9 10.50	.... 1.87	7 8.63	1 1.40	11.62 14.31
0.82 1.23	9 10.55	.... 1.80	7 8.75	1 1.54	11.62 15.21
....	16 18.55	.... 1.30	14 17.25	....	14.00 17.25
1.65 1.94	10 11.50	.... 2.15	8 9.35	5 5.40	19.17 21.97
....	12 12.80	.... 2.37	10 10.43	5 5.34	11.50 15.21
....	12 13.30	.... 2.36	10 10.94	5 5.73	11.50 16.10
....	12 13.95	.... 2.25	10 11.70	....	10.00 11.70

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	American Agricultural Chemical Co.—Con.		
3231	Boar's Head Sugar Beet Grower	Davison	Claimed Found
3232	Boar's Head Sure Growth Potash Manure	Alma	Claimed Found
3233	Boar's Head 10 per cent Potash Composition	Davison	Claimed Found
3279	Boar's Head World of Good Superphosphate	Portland	Claimed Found
	American Fertilizer Company, Chicago, Ill.		
3068	Union Brand Complete Crop Grower	Ypsilanti	Claimed Found
3315	Union Brand Complete Crop Grower	Pontiac	Claimed Found
3069	Union Brand Corn and General Crop Grower	Saginaw	Claimed Found
3316	Union Brand Corn and General Crop Grower	Pontiac	Claimed Found
3070	Union Brand Dissolved Bone and Potash	Hudson	Claimed Found
3178	Union Brand General Cropper	Bad Axe	Claimed Found
3234	Union Brand High Grade Acid Phosphate	Bay Port	Claimed Found
3071	Union Brand Gardeners Favorite	Bay City	Claimed Found
3179	Union Brand High Grade Celery and General Trucker	Deckerville	Claimed Found
3072	Union Brand High Grade Phosphate and Potash	Tecumseh	Claimed Found

1912, expressed in parts per one hundred.—Con.

Nitrogen.	Phosphoric Acid. Total.	Phosphoric Acid. Insoluble.	Phosphoric Acid. Available.	Potash	Valuation.
1.23 1.36	11 12.65	.... 2.15	9 10.50	2 2.28	$15.98 18.27
0.82 1.02	10 10.60	.... 1.42	8 9.18	3 3.22	14.42 16.28
0.82 0.94	7 7.80	.... 1.30	5 6.50	10 10.70	17.72 20.00
2.06 2.27	10 10.75	.... 0.17	8 10.58	1.50 1.71	17.18 20.27
1.65 2.26	.... 11.45	1.50 3.40	8 8.05	2 3.15	16.27 20.30
1.65 1.63	.... 11.00	1.50 2.74	8 8.26	2 2.38	16.27 17.30
0.82 0.97	.... 10.60	1 0.75	8 9.85	4 4.05	14.92 17.25
0.82 1.16	.... 10.50	1 0.90	8 9.60	4 **3.73**	11.92 17.46
0.40 0.84	.... 14.65	1 1.70	10 12.95	5 5.63	16.32 21.69
0.82 0.91	.... 10.55	1 2.20	8 8.35	1 1.25	12.22 13.70
....	.... 17.75	1 1.85	14 15.90	....	14.00 15.90
3.20 3.54	.... 12.30	2 4.15	9 **8.15**	10 10.98	30.19 32.29
0.82 0.86	.... 7.85	1 1.32	6 6.53	10 11.31	18.32 20.33
....	.... 13.20	1 1.55	10 11.65	2 3.32	11.80 14.61

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	American Fertilizer Co., Chicago, Ill.—Con.		
3317	Union Brand High Grade Phosphate and Potash	Bad Axe	Claimed Found
3073	Union Brand High Grade Sugar Beet Grower	Bay City	Claimed Found
3074	Union Brand King's Favorite	Ypsilanti	Claimed Found
3337	Union Brand King's Favorite	Capac	Claimed Found
3077	Union Brand Pure Bone Meal	Hudson	Claimed Found
3078	Union Brand Pure Bone Meal and Potash	Tecumseh	Claimed Found
3075	Union Brand Onion, Potato and Tobacco Grower	Saginaw	Claimed Found
3076	Union Brand Onion, Potato and Tobacco Grower	Tecumseh	Claimed Found
3318	Union Brand Onion, Potato and Tobacco Grower	Pontiac	Claimed Found
3079	Union Brand Steamed Bone Meal	Bay City	Claimed Found
	Armour Fertilizer Works, Chicago, Ill.		
3319	All Soluble	Coloma	Claimed Found
3080	All Soluble	Bay City	Claimed Found
3245	Ammoniated Bone with Potash	Camden	Claimed Found
3081	Armour's Bone Meal	Lansing	Claimed Found

1912, expressed in parts per one hundred.—Con.

Nitrogen.	Phosphoric Acid. Total.	Phosphoric Acid. Insoluble.	Phosphoric Acid. Available.	Potash.	Valuation.
....	.... 12.10	1 2.08	10 10.02	2 2.47	$11.80 12.24
1.65 1.64	.... 11.60	1.50 3.20	8 8.40	5 5.05	18.97 20.67
0.82 1.08	.... 10.50	1 1.55	8 8.95	3 3.70	11.02 16.75
0.82 1.01	.... 10.30	1 2.28	8 8.02	3 3.32	11.02 15.51
2.50 2.60	25 25.65	....	....	....	28.91 29.78
0.82 **0.66**	20 20.50	....	....	3 3.86	21.62 22.22
1.65 1.78	.... 10.65	1.50 2.37	8 8.28	7 7.59	20.77 22.40
1.65 1.71	.... 12.05	1.50 2.15	8 9.90	7 8.49	20.77 24.49
1.65 1.67	.... 11.10	1.50 1.04	8 10.06	7 7.72	20.77 23.38
0.82 1.43	30 30.10	....	....	....	26.92 29.17
2.88 2.89	.... 10.45	0.50 1.46	8 8.99	4 4.18	22.05 23.61
2.88 3.16	.... 10.40	0.50 1.97	8 8.43	4 4.13	22.05 24.19
2.47 2.51	.... 8.30	0.50 2.22	6 6.08	2 2.52	16.80 18.18
1.65 2.47	27 28.10	....	....	....	27.47 31.28

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	Armour Fertilizer Works, Chicago, Ill.—Con.		
3082	Armour's Standard	Lake Odessa	Claimed Found
3083	Banner Brand	Lake Odessa	Claimed Found
3084	Bone, Blood and Potash	Saginaw	Claimed Found
3085	Crop Grower	Lansing	Claimed Found
3320	Crop Grower	St. Louis	Claimed Found
3086	Fruit and Root Crop Special	Quincy	Claimed Found
3087	Grain Grower	Lansing	Claimed Found
3088	High Grade Potato	Quincy	Claimed Found
3339	High Grade Potato	Pigeon	Claimed Found
3280	Mixed Bone and Potash	Manufacturer's sample	Claimed Found
3208	Muriate of Potash	Nunica	Claimed Found
3180	Phosphate and Potash	Coopersville	Claimed Found
3283	Potash Trucker	Manufacturer's Sample	Claimed Found
3090	Soluble Phosphate and Potash	Saginaw	Claimed Found
3246	Star Phosphate	Camden	Claimed Found

1912, expressed in parts per one hundred. Con.

Nitrogen.	Phosphoric Acid.			Potash.	Valuation.
	Total.	Insoluble.	Available.		
0.82 1.01	.... 9.90	0.50 1.65	8 8.25	3 3.20	$13.82 15.38
....	.... 13.05	0.50 1.62	10 11.43	8 8.25	17.20 18.86
1.11 4.01	.... 10.80	0.50 1.37	8 9.13	7 7.95	29.13 31.53
1.21 1.26	.... 9.95	0.50 1.54	8 8.41	2 2.01	14.31 15.32
1.21 1.28	.... 9.75	0.50 1.44	8 8.31	2 2.11	14.31 15.35
1.65 1.81	.... 10.45	0.50 1.70	8 8.75	5 5.68	18.57 20.98
1.65 1.77	.... 10.50	0.50 1.57	8 8.93	2 2.52	15.87 18.13
1.65 1.73	.... 9.80	0.50 1.16	8 8.64	10 10.79	23.07 24.97
1.65 1.74	.... 9.65	0.50 0.82	8 8.83	10 11.98	23.07 26.13
0.82 1.59	18 19.60	....	....	4 4.11	20.92 25.04
....	....	....	....	50 50.60	45.00 15.54
....	.... 12.40	0.50 0.80	10 11.60	2 2.35	11.80 13.72
0.82 0.90	.... 9.50	0.50 1.18	8 8.32	8 9.14	18.32 20.22
....	.... 12.30	0.50 1.22	10 11.08	4 4.14	13.60 11.81
....	.... 17.20	0.50 1.57	14 15.63	....	14.00 15.63

Results of analyses of commercial fertilizers for

Laboratory number	Trade name.	Locality where sample was taken.	
	Armour Fertilizer Works, Chicago, Ill.—Con.		
3089	Sugar Beet Special	Quincy	Claimed Found
3091	Sugar Beet Special	Saginaw	Claimed Found
3092	1-5-10 Fertilizer	Bay City	Claimed Found
3093	10-5 Fertilizer	Ida	Claimed Found
3094	Wheat, Corn and Oats Special	Lansing	Claimed Found
	Bash Fertilizer & Chemical Co., Ft. Wayne Ind		
3095	Bashumus Corn Special	Lansing	Claimed Found
3096	Bashumus Garden Special	Lansing	Claimed Found
3097	Bashumus Grain Grower	Lansing	Claimed Found
	Robert Binder Estate, Battle Creek, Mich.		
3247	Blood and Bone	Battle Creek	Claimed Found
	James Boland Rendering and Fertilizer Co. Jackson, Mich.		
3098	General Crop	Jackson	Claimed Found
3099	Sugar Beet	Jackson	Claimed Found
	International Agricultural Corporation. Buffalo Fertilizer Works, Buffalo, N. Y.		
3248	Bone Meal	Plymouth	Claimed Found
3209	Celery and Potato Special	Hudsonville	Claimed Found

1910, expressed in parts per one hundred.—Con.

Nitrogen.	Phosphoric Acid. Total.	Phosphoric Acid. Insoluble.	Phosphoric Acid. Available.	Potash.	Valuation.
0.82 0.91	.... 10.40	0.50 2.17	8 8.23	4 4.65	$11.72 16.64
0.82 1.11	.... 10.90	0.50 1.72	8 9.18	4 4.41	11.72 17.79
0.82 0.90	.... 6.65	0.50 1.37	5 5.28	10 10.65	17.12 18.63
....	.... 11.50	0.50 0.95	10 10.55	5 5.11	14.50 15.15
0.82 1.02	.... 8.00	0.50 1.00	7 7.00	1 1.20	11.02 12.17
1.00 1.11	.... 9.95	1.00 0.30	8 9.65	4 4.65	15.56 17.91
1.00 **0.82**	.... 9.95	1 0.42	8 9.53	10 **9.26**	20.96 20.95
1.20 1.45	.... 9.40	1 1.44	8 7.96	2 2.06	14.48 15.55
5.25 6.22	13.17 15.85	....	....	....	29.24 31.83
1.25 3.40	.... 14.70	.... 8.15	7 **6.55**	1.25 1.25	12.58 23.04
2.50 3.10	.... 13.92	.... 3.10	10 10.82	3 **2.74**	21.60 25.57
2.90 3.58	22 22.20	....	....	....	27.92 30.51
1.60 1.63	.... 10.65	1 2.65	8 8.00	10 11.80	23.10 25.48

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	International Agricultural Corporation, Buffalo Fertilizer Works, Buffalo, N. Y.—*Con.*		
3100	Dissolved Potash	Belleville	Claimed Found
3101	Extra Phosphate and Potash	Blissfield	Claimed Found
3102	Farmers Choice	Coldwater	Claimed Found
3321	Farmers Choice	Coopersville	Claimed Found
3103	General Crop	Coldwater	Claimed Found
3104	General Favorite	Blissfield	Claimed Found
3338	General Favorite	Coopersville	Claimed Found
3105	Lillie's Special, No. 1	Blissfield	Claimed Found
3106	Lillie's Special, No. 2	Coldwater	Claimed Found
3210	Ohio and Michigan Special	Hartford	Claimed Found
3107	York State Special	Coldwater	Claimed Found
	E. Burton, St. Joseph, Mich.		
3211	Meat and Bone Phosphate	St. Joseph	Claimed Found
	Chicago Fertilizer & Chemical Works, Chicago, Ill.		
3305	Animal Bone and Potash	Manufacturer's sample	Claimed Found
3306	Universal Wheat, Corn and Oats	Manufacturer's sample	Claimed Found

1912, expressed in parts per one hundred.—Con.

Nitrogen.	Phosphoric Acid.			Potash.	Valuation.
	Total.	Insoluble.	Available.		
....	.... 15.15	1 1.12	14 14.33	....	$14.00 14.33
....	.... 12.07	1 1.90	10 10.17	8 8.03	17.20 17.40
0.80 1.36	.... 11.00	1 2.06	8 8.94	5 5.07	15.75 19.16
0.80 1.07	.... 11.20	1 1.78	8 9.42	5 5.20	15.75 18.62
....	.... 13.55	1 2.52	9 11.03	3 3.17	11.70 13.88
1.20 1.49	.... 10.53	1 2.25	8 8.28	2.50 3.24	14.92 17.41
1.20 1.47	.... 11.40	1 2.10	8 9.20	2.50 3.13	14.92 18.10
0.80 0.98	.... 12.50	1 2.82	9 9.68	2 2.14	14.05 16.23
1.60 1.78	.... 10.95	1 2.87	8 8.08	4 4.40	17.70 19.53
0.80 1.02	.... 11.10	1 2.00	10 12.10	1 2.28	14.15 18.58
1.60 1.52	.... 11.15	1 1.52	9 9.93	5 **4.11**	19.60 19.66
3 3.50	15 16.95	.... 4.52	.... 12.43	0.36 0.21	26.00 26.90
1.64 1.85	.... 11.10	2 1.60	8 9.50	2 2.42	16.44 18.90
0.82 1.14	.... 9.45	1 1.00	8 8.45	2 3.02	13.12 15.63

Results of analyses of commercial fertilizers for

Laboratory number	Trade name.	Locality where sample was taken.	
	Chicago Raw Products Co., Chicago, Ill.		
3265	Consumers Special Corn and Oats Fertilizer	Capac	Claimed Found
3212	Consumers Special Corn and Wheat Grower	Mayville	Claimed Found
3286	Consumers Special Farmers Favorite	Manufacturer's sample	Claimed Found
3261	Consumers Special High Grade Wheat Grower	Capac	Claimed Found
3213	Consumers Special Onion and Vegetable Grower	Mayville	Claimed Found
3211	Consumers Special Vine and Tree Grower	Mayville	Claimed Found
3322	Consumers Special Vine and Tree Grower	Capac	Claimed Found
	The Cincinnati Phosphate Co., Cincinnati, Ohio.		
3181	Black Soil Fertilizer	Grand Rapids	Claimed Found
3250	Bone and Phosphate Mixture Wheat Special	Lakeview	Claimed Found
3182	Dissolved Phosphate and Potash	Grand Rapids	Claimed Found
3323	Dissolved Phosphate and Potash	E. Saugatuck	Claimed Found
3111	Grain and Grass Grower	Hand Station	Claimed Found
3112	Tobacco, Potato and Beet Grower	Hand Station	Claimed Found
3324	Tobacco, Potato and Beet Grower	E. Saugatuck	Claimed Found

1912, expressed in parts per one hundred.—Con.

Nitrogen.	Phosphoric Acid. Total.	Phosphoric Acid. Insoluble.	Phosphoric Acid. Available.	Potash.	Valuation.
....	.... 11.80	1 0.97	10 10.83	2 2.32	$11.80 12.92
0.80 0.82	.... 10.25	1 0.66	8 9.59	4 4.47	11.85 16.79
0.80 0.87	.... 10.10	1 1.25	8 8.85	3 3.46	13.95 15.55
....	.... 11.40	1 0.87	10 10.53	5 5.07	14.50 15.09
....	.... 12.10	1 1.00	10 11.10	10 10.53	19.00 20.58
0.80 1.51	20 27.80	....	....	8 **7.36**	26.05 34.34
0.80 1.43	20 21.00	....	....	8 9.29	26.05 30.25
....	.... 11.00	1 0.80	8 10.20	8 8.07	15.20 17.46
1.60 1.67	.... 18.25	6 6.65	10 11.60	1 0.97	19.00 21.08
....	.... 12.75	1 0.97	10 11.78	4 4.21	13.60 15.57
....	.... 11.10	1 0.90	10 10.20	4 4.41	13.60 14.17
0.80 0.86	.... 10.35	1 1.20	8 9.15	2 2.19	13.05 14.66
0.80 0.84	.... 10.30	1 0.67	8 9.63	4 3.94	11.85 16.44
0.80 0.95	.... 10.60	1 0.52	8 10.08	4 3.85	14.85 17.11

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	The Cincinnati Phosphate Co., Cincinnati, Ohio.—*Con.*		
3113	Truck and Tobacco Fertilizer	Vermontville	Claimed.... Found.....
3215	Wheat Grower	Holland	Claimed.... Found ....
	Darling & Co., Chicago, Ill.		
3114	Big Potash Brand	Lansing	Claimed.... Found ....
3115	Chicago Brand	Birmingham	Claimed.... Found.....
3325	Chicago Brand	Dowagiac	Claimed.... Found.....
3287	Eight per cent Phosphate	Manufacturer's sample	Claimed.... Found.....
3116	Farmers Favorite Brand	Lansing	Claimed.... Found.....
3117	General Crop Brand	Bay City	Claimed.... Found.....
3340	General Crop Brand	Clinton	Claimed.... Found.....
3332	High Grade Acid Phosphate	Manufacturer's sample	Claimed.... Found ....
3183	Phosphate and Potash Brand	Sebewaing	Claimed.... Found.....
3216	Pure Bone and Potash	Mayville	Claimed.... Found.....
3252	Pure Bone and Potash	Charlotte	Claimed.... Found.....
3335	Pure Ground Bone	Manufacturer's sample	Claimed.... Found.....

1912, expressed in parts per one hundred.—Con.

Nitrogen.	Phosphoric Acid.			Potash.	Valuation.
	Total.	Insoluble.	Available.		
1.60 1.55	.... 7.65	1 1.00	6 6.65	6 6.08	$17 50 18 14
....	.... 17.00	1 1.62	14 15.38	....	14 00 15 38
1.24 1.21	.... 11.25	2 1.52	8 9.73	10 10.73	22 22 24 31
1.65 1.76	.... 11.10	2 1.67	8 9.43	2 2.16	16 47 18 31
1.65 1.88	.... 10.95	2 1.84	8 9.11	2 2.33	16 47 18 64
....	.... 9.20	.... 0.87	8 8.33	....	8 00 8 33
2.47 2.05	.... 11.05	2 1.76	8 9.29	4 5.14	21 20 21 92
0.82 0.93	.... 9.78	2 1.67	8 8.11	6 6.40	17 12 17 85
0.82 1.00	.... 10.80	2 1.24	8 9.56	6 6.32	17 12 19 31
....	.... 15.80	.... 1.10	14 14.70	....	14 00 14 70
....	.... 11.45	.... 0.60	10 10.85	2 2.68	11 80 13 26
1.65 1.52	24.25 26.15	....	....	6 6.18	30 67 31 89
1.65 1.63	24.25 26.40	....	....	6 6.71	30 67 32 96
1.85 2.19	28 30.00	....	....	....	28 98 31 80

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	Darling & Co., Chicago, Ill.—*Con.*		
3118	Sugar Beet and Root Grower	Clinton	Claimed Found
3119	Sure Winner Brand	Clinton	Claimed Found
3266	Ten Five Brand	Lambs	Claimed Found
3120	Vegetable and Lawn Fertilizer	Coldwater	Claimed Found
3288	Kainit	Manufacturer's sample	Claimed Found
3289	Muriate of Potash	Manufacturer's sample	Claimed Found
3251	Nitrate of Soda	White Pigeon	Claimed Found
	German Kali Works, Baltimore, Md.		
3121	Kainit	Adrian	Claimed Found
3290	Muriate of Potash	Manufacturer's sample	Claimed Found
3291	Sulfate of Potash	Manufacturer's sample	Claimed Found
	Gleaners Clearing House Association, Detroit, Mich.		
3283	Gleaner Acid Phosphate	Manufacturer's sample	Claimed Found
3108	Gleaner Michigan Favorite	Mason	Claimed Found
3284	Gleaner Michigan General Grower	Manufacturer's sample	Claimed Found
3106	Gleaner Michigan Producer	Mason	Claimed Found

1912, expressed in parts per one hundred.—Con.

Nitrogen.	Phosphoric Acid. Total.	Phosphoric Acid. Insoluble.	Phosphoric Acid. Available.	Potash.	Valuation.
1.65 1.91	.... 10.80	2 2.40	8 8.70	5 5.57	$19.17 21.35
0.82 0.77	.... 9.10	2 1.06	8 8.04	3 3.12	11.42 11.02
....	.... 11.20	.... 0.65	10 10.55	5 4.92	14.50 11.98
3.30 3.52	.... 10.85	2 2.07	8 8.78	7 7.05	26.86 28.50
....	....	....	....	12.40 15.72	11.16 14.15
....	....	....	....	50 51.98	45.00 46.78
14.75 14.88	....	....	....	....	52.51 52.97
....	....	....	....	12 13.32	10.80 11.99
....	....	....	....	50 50.66	45.00 45.59
....	....	....	....	48 48.54	43.20 43.69
....	.... 16.30	0.50 0.22	14 16.08	....	14.00 16.08
1.65 1.92	.... 10.90	0.50 2.25	8 8.65	4 4.55	17.67 20.49
0.82 0.83	.... 12.10	0.50 1.86	10 10.24	1 1.09	14.02 14.91
....	.... 12.50	0.50 1.00	10 11.50	8 8.65	17.20 19.29

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	Gleaners Clearing House Association, Detroit, Mich.—*Con.*		
3110	Gleaner Michigan Special	Petersburg	Claimed.... Found ....
3285	Gleaner Phosphate and Potash	Manufacturer's sample	Claimed.... Found ....
	Grand Rapids Glue Co., Grand Rapids, Mich.		
3184	Grand Rapids"	Grand Rapids	Claimed.... Found ....
	Grange Fertilizer Co., Detroit, Mich.		
3292	All Crops Special Fertilizer	Manufacturer's sample	Claimed.... Found....
3293	Complete Manure	Manufacturer's sample	Claimed .. Found. ..
3253	Corn, Oats and Grass Fertilizer	Plymouth	Claimed .. Found. ..
3294	High Grade Concentrated Wheat Manure	Manufacturer's sample	Claimed.... Found ....
3122	Potato and Vegetable Fertilizer	Romulus	Claimed .. Found. ..
3295	Wheat Fertilizer, No. 1	Manufacturer's sample	Claimed.... Found....
3123	Wheat Fertilizer with Potash	Ypsilanti	Claimed.... Found.....
	Hirsh, Stein & Co., Chicago, Ill.		
3186	Calumet 14 per cent Acid Phosphate	Ubly	Claimed .. Found.....
3127	Calumet Bone Black Grain Grower	Reading	Claimed ... Found. ...
3128	Calumet Bone Phosphate and Potash	Clayton	Claimed ... Found. ..

1912, expressed in parts per one hundred.—Con.

Nitrogen.	Phosphoric Acid. Total.	Phosphoric Acid. Insoluble.	Phosphoric Acid. Available.	Potash.	Valuation.
0.82 0.80	.... 9.65	0.50 1.50	8 8.15	4 1.55	$11.72 15.70
....	.... 10.40	0.50 0.58	10 9.82	2 2.01	11.80 11.66
2.00 1.93	.... 20.50	5.00 5.87	10 14.63	1 0.70	20.02 24.48
1.03 1.02	10 10.95	.... 2.45	8 8.50	2 2.42	14.27 15.29
0.82 0.90	9 10.90	.... 1.30	7 9.60	1 1.21	11.62 14.40
1.65 1.66	10 11.40	.... 1.72	8 9.68	2 2.25	16.47 18.31
1.23 1.38	11 13.15	.... 2.07	9 11.08	2 2.30	15.98 18.89
0.82 1.02	10 11.50	.... 1.67	8 9.83	3 3.23	14.42 17.04
....	16 20.50	.... 3.10	11 17.40	....	14.00 17.40
....	12 13.85	.... 3.62	10 10.23	2 2.05	11.80 12.08
....	.... 17.50	1 1.02	11 16.48	....	14.00 16.48
2.05 2.08	.... 11.05	1 1.72	8 9.33	1.50 1.86	17.05 19.09
....	.... 11.85	1 0.82	10 11.03	2 2.55	11.80 13.33

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	Hirsh, Stein & Co., Chicago, Ill.—*Con.*		
3129	Calumet Corn and Wheat Grower	Birmingham	Claimed Found
3185	Calumet Grain Grower	Washington	Claimed Found
3130	Calumet High Grade Bone Phosphate and Potash	Hudson	Claimed Found
3131	Calumet Potato, Tobacco and Onion Grower	Deerfield	Claimed Found
3187	Calumet Special Grape Fertilizer	Memphis	Claimed Found
3217	Calumet Special 10 per cent Potash Manure	Zeeland	Claimed Found
3334	Calumet Sugar Beet and General Crop Fertilizer	Manufacturer's sample	Claimed Found
3188	Calumet Sure Growth Fertilizer	Washington	Claimed Found
3189	Calumet 10-10 Hummer Potash Phosphate	Washington	Claimed Found
3132	Calumet Wheat, Corn and Oats Special	Hudson	Claimed Found
	The Independent Packers Fertilizing Co., Columbus, Ohio.		
3133	Number 3, Corn, Wheat, Oats and Clover	Addison	Claimed Found
3134	Number 1, Tobacco, Potato, Onion and Truck Special	Addison	Claimed Found
3135	Number 8, Phosphate and Potash	Addison	Claimed Found
3136	Number 11, Special Sugar Beet Fertilizer	Addison	Claimed Found

1912, expressed in parts per one hundred.—Con.

Nitrogen.	Phosphoric Acid.			Potash.	Valuation.
	Total.	Insoluble.	Available.		
0.82 0.77	.... 9.85	1 0.65	8 9.20	4 4.65	$14 92 16 39
1.60 1.56	.... 11.90	1 1.65	8 10.25	2 2.68	15 90 18 88
....	.... 11.95	1 1.02	10 10.93	5 5.00	14 50 15 43
1.60 1.64	.... 11.25	1 2.20	8 9.05	5 5.93	18 60 21 11
0.80 1.14	20 24.00	....	....	8 8.10	26 05 30 55
0.82 0.79	.... 6.60	0.50 1.02	5 5.58	10 **9.72**	17 12 17 56
1.24 1.80	.... 10.35	1 1.43	9 8.92	2 2.70	15 62 18 33
0.80 1.00	.... 11.10	1 1.00	8 10.10	2 2.26	13 05 16 09
....	.... 13.20	1 0.52	10 12.68	10 10.67	19 00 22 28
0.82 0.77	.... 10.95	1 1.35	8 9.60	3 3.29	14 02 15 84
0.82 1.01	.... 10.85	.... 1.05	8 9.80	4 4.66	14 52 18 00
0.82 0.94	.... 8.35	.... 1.00	6 7.25	8 8.76	16 12 18 98
....	.... 11.80	.... 0.35	10 11.45	2 3.91	11 80 14 97
0.82 0.97	.... 9.35	1 0.92	8 8.43	4 4.41	14 92 16.22

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	The Jarecki Chemical Co., Sandusky, Ohio.		
3137	Black Soil Special	Reading	Claimed Found
3138	C. O. D. Phosphate	Mason	Claimed Found
3139	Fish, Phosphate and Potash Tobacco and Potato Food	Adrian	Claimed Found
3140	Lake Erie Guano with Phosphate and Potash	Reading	Claimed Found
3141	Number One Formula	Tecumseh	Claimed Found
3142	Special Sugar Beet Grower	Petersburg	Claimed Found
3143	Square Brand Phosphate and Potash	Tecumseh	Claimed Found
3251	Tobacco and Truck Grower	Zeeland	Claimed Found
	Kalamazoo Rendering and Fertilizer Co., Kalamazoo, Mich.		
3335	Kazoo	Manufacturer's sample	Claimed Found
	Natural Guano Co., Aurora, Ill.		
3218	Sheep's Head Brand Pulverized Sheep Manure	Benton Harbor	Claimed Found
	Nitrate Agencies Co., Chicago, Ill.		
3296	Acid Phosphate	Manufacturer's sample	Claimed Found
3297	Muriate of Potash	Manufacturer's sample	Claimed Found
3298	Nitrate of Soda	Manufacturer's sample	Claimed Found

1912, expressed in parts per one hundred.—Con.

Nitrogen.	Phosphoric Acid. Total.	Phosphoric Acid. Insoluble.	Phosphoric Acid. Available.	Potash.	Valuation.
....	.... 9.20	1 0.70	8 8.50	8 8.17	$15 20 15 85
....	.... 18.40	1 1.32	11 17.08	....	11 00 17 08
0.83 0.87	.... 9.75	1 1.20	8 8.55	4 4.36	11 95 16 04
1.25 1.35	.... 10.30	1 1.67	8 8.63	2.50 2.91	15 10 16 76
0.83 0.91	.... 11.50	1 0.92	8 10.58	2 2.01	13 16 16 00
0.83 0.86	.... 9.90	1 0.60	8 9.30	4 4.20	14 96 16 38
....	.... 11.75	1 1.40	10 10.35	2 2.07	11 80 12 21
1.66 1.76	.... 6.62	1 0.82	6 5.80	6 7.39	17 71 19 05
1.50 2.09	.... 8.35	2 50 5 30	6 3 05	3 5.48	15 04 17 51
2.25 2.65	.... 1.80	.... 0 17	1.50 1.63	1.50 2.17	10 85 13 08
....	.... 16.90	.... 2 02	14 11 88	....	14 00 14 88
....	....	....	....	50 50 56	45 00 45 50
15 15.09	....	....	....	....	53 40 53 72

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	The Packers Fertilizer Co., Cincinnati, Ohio.		
3336	Acidulated Phosphate and Potash	Manufacturer's sample	Claimed
			Found
3192	Animal Tankage Phosphate and Potash	Sebewaing	Claimed
			Found
3193	High Potash Manure	Sebewaing	Claimed
			Found
3307	Phosphate with Humus	Manufacturer's sample	Claimed
			Found
3194	Sweepstakes	Sebewaing	Claimed
			Found
	Pioneer Fertilizer Co., Chicago, Ill.		
3146	Pioneer General Crop Grower	Ypsilanti	Claimed
			Found
3341	Pioneer General Crop Grower	Kibbie	Claimed
			Found
3147	Pioneer High Grade Acid Phosphate	Dundee	Claimed
			Found
3148	Pioneer High Grade Phosphate and Potash	Dundee	Claimed
			Found
[illegible]	Pioneer 1 7 1 Fertilizer	Manufacturer's sample	Claimed
			Found
3219	Pioneer Potato and Vegetable Grower	Kibbie	Claimed
			Found
3149	Pioneer Truck and Corn Grower	Dundee	Claimed
			Found
	The Pulverized Manure Co., Chicago, Ill		
[illegible]	Wizard Brand Manure	Detroit	Claimed
			Found
3145	Wizard Brand Pulverized Sheep Manure	Lansing	Claimed
			Found

1912, expressed in parts per one hundred.—Con.

Nitrogen.	Phosphoric Acid — Total.	Phosphoric Acid — Insoluble.	Phosphoric Acid — Available.	Potash.	Valuation.
....	.... 13.40	1 1.51	10 11.96	2 2.55	$11 80 14 26
0.80 0.83	.... 10.15	1 0.37	8 9.78	4 4.56	14 85 16 98
0.80 0.81	.... 8 05	1 1.05	6 7.00	8 8.18	16 45 17 66
0.40 0.44	.... 15.90	1 1 14	12 14.76	....	13 82 16 79
1.20 1.56	.... 10.45	1 1.51	8 8.91	2.50 2.35	14 92 17 20
1.65 1.85	.... 12.35	1 4.70	8 7.65	2 2.21	16 07 18 11
1.65 1.56	.... 11.10	1 1.52	8 9.58	2 2.98	16 07 18 43
....	.... 17.10	1 1.07	14 16.03	....	14 00 16 03
....	.... 12.70	1 1.02	10 11.68	4 3.88	13 60 15 17
0.82 1.10	.... 9.85	1 2.20	7 7 65	1 1.96	11 22 14 22
1.65 1 44	.... 11.15	1 1.55	8 9.60	7 7.33	20 57 21 95
0.82 0.88	.... 10.75	1 1.35	8 9.40	4 4.25	14 92 16 90
1.80 2.01	.... 1.75	.... 0.17	1 1.58	1 2.09	8 31 10 68
1.80 2.64	.... 1.75	.... 0.10	1 1.65	1 1.96	8 31 12 85

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	Elmer D. Smith & Co., Adrian, Mich.		
3303	Fertilene	Manufacturer's sample	Claimed Found
	The Smith Agricultural Chemical Co., Columbus, Ohio.		
3190	Black Soil Formula	Verona Mills	Claimed Found
3150	Special Potato Formula	Quincy	Claimed Found
3255	Chicago Fertilizer Co's. B. B. & P. Brand	Petersburg	Claimed Found
3151	Chicago Fertilizer Co's. Calumet Phosphate	Carlton	Claimed Found
3152	Chicago Fertilizer Co's. Diamond Phosphate and Potash.	Carlton	Claimed Found
3153	Chicago Fertilizer Co's. New Leader	Quincy	Claimed Found
3154	Chicago Fertilizer Co's. Potash Special	Petersburg	Claimed Found
3155	Chicago Fertilizer Co's. Western Phosphate and Potash.	Petersburg	Claimed Found
3156	Ohio Farmers' Ammoniated Phosphate and Potash	Adrian	Claimed Found
3256	Ohio Farmers' Climax Phosphate	Hillsdale	Claimed Found
3157	Ohio Farmers' Corn, Oats and Wheat Fertilizer	Adrian	Claimed Found
3257	Ohio Farmers' Excelsior Phosphate	Petersburg	Claimed Found
3258	Ohio Farmers' Soluble Phosphate and Potash	Hillsdale	Claimed Found
3158	Ohio Farmers' Wheat Maker and Seeding Down	Adrian	Claimed Found

1912, expressed in parts per one hundred.—Con.

Nitrogen.	Phosphoric Acid. Total.	Insoluble.	Available.	Potash.	Valuation.
12 12.75	.... 26.50	....	25 26.50	25 25.82	$90 22 95 13
....	.... 11.65	.... 0.87	10 10.78	10 10.93	19 00 20 52
0.80 0.95	.... 8.85	.... 1.12	6 7.73	10 11.33	17 85 21 76
1.60 1.62	.... 10.70	.... 2.67	8 8.03	2 2.31	15 50 16 95
....	.... 11.85	.... 1.10	10 10.75	2 2.31	11 80 12 83
....	.... 12.05	.... 0.90	10 11.15	5 6.41	14 50 16 92
0.80 0.93	.... 9.95	.... 1.15	8 8.80	7 7.46	17 15 19 28
0.80 0.90	.... 10.55	.... 1.45	8 9.10	4 4.68	14 45 17 09
0.80 0.94	.... 10.00	.... 1.55	8 8.45	2 2.38	12 65 14 56
0.80 0.87	.... 10.20	.... 1.32	8 8.88	4 4.32	14 45 16 40
....	.... 10.80	.... 0.90	10 9.90	5 5.40	14 50 14 76
1.60 1.76	.... 10.45	.... 1.32	8 9.13	2 2.50	15 50 18 17
0.80 0.97	.... 9.65	.... 1.05	8 8.60	7 7.46	17 15 19 18
....	.... 11.75	.... 1.20	10 10.55	2 2.30	11 80 12 62
0.80 0.94	.... 10.20	.... 1.50	8 8.70	2 2.13	12 65 14 56

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	Speidel & Swartz, Grand Haven, Mich.		
3220	Celery Hustler	Grand Haven	Claimed.... Found.....
	Sullivan Packing Co., Detroit, Mich.		
3308	Crystal	Manufacturer's sample	Claimed.... Found ....
	Swift & Co., Chicago, Ill.		
3159	Bean and Grain Grower	Petersburg	Claimed.... Found ....
3326	Bean and Grain Grower	Capac	Claimed.... Found ...
3160	Complete Fertilizer	New Boston	Claimed.... Found ....
3260	Early Potato and Vegetable Grower	Dearborn	Claimed.... Found ...
3342	Early Potato and Vegetable Grower	Jackson	Claimed.... Found ..
3261	Garden City Phosphate	Reading	Claimed ... Found ..
3161	Onion, Potato and Tobacco Fertilizer	Leslie	Claimed.... Found ....
3195	Park and Lawn Fertilizer	Grand Rapids	Claimed .... Found ...
3221	Potato, Celery and Onion Grower	Zeeland	Claimed.... Found ..
3163	Pure Dissolved Animal Bone and Potash	Dundee	Claimed ... Found ..
3162	Pure Bone Meal	Jackson	Claimed .. Fund
3313	Pure Bone Meal	Grand Rapids	Claimed Found..

1912, expressed in parts per one hundred.—Con.

Nitrogen.	Phosphoric Acid.			Potash.	Valuation.
	Total.	Insoluble.	Available.		
6 6.01	.... 4.90	0.69 1.77	3.17 3.13	1.25 1.25	$25.94 26.37
6.50 7.58	.... 7.25	0.50 2.62	6 **4.63**	0.75 **0.36**	30.02 32.98
0.82 1.05	.... 10.45	1 1.45	8 9.00	3 2.92	14.02 15.95
0.82 0.95	.... 10.35	1 1.41	8 8.91	3 3.35	14.02 15.89
0.82 1.07	.... 10.55	1 1.57	8 8.98	1 2.01	12.22 15.23
3.29 **3.07**	.... 7.60	1 1.02	6 6.58	10 10.32	27.12 27.21
3.29 3.69	.... 9.00	1 1.40	6 7.60	10 11.56	27.12 31.70
....	.... 16.15	1 1.17	14 14.98	....	14.00 14.98
1.65 1.71	.... 11.45	1 0.90	8 10.55	7 7.42	20.57 23.68
6.58 6.54	8 9.00	....	....	....	29.85 30.50
0.82 0.79	.... 7.50	1 1.02	5 6.48	10 10.02	17.32 18.72
1.44 1.74	.... 20.80	2 5.32	16 **15.48**	4 4.16	25.53 27.54
2.47 2.49	24 25.60	....	....	....	28.00 29.35
2.47 3.25	24 25.30	....	....	....	28.00 31.82

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	Swift & Co., Chicago, Ill.—*Con.*		
3235	Pure Raw Bone Meal	Grand Rapids	Claimed Found
3164	Special Phosphate and Potash	Petersburg	Claimed Found
3165	Sugar Beet Grower	Bay City	Claimed Found
3327	Sugar Beet Grower	Hudsonville	Claimed Found
3191	Sugar Beet Special	St. Clair	Claimed Found
3328	Superphosphate	New Boston	Claimed Found
3166	Superphosphate	Hudson	Claimed Found
3167	Truck Grower	Reading	Claimed Found
3262	Muriate of Potash	Reading	Claimed Found
	Tuscarora Fertilizer Co., Chicago, Ill.		
3300	Acid Phosphate	Manufacturer's sample	Claimed Found
3222	Ammoniated Phosphate	New Buffalo	Claimed Found
3223	Bone and Potash	New Buffalo	Claimed Found
3267	Michigan Special	Port Huron	Claimed Found
3301	Tuscarora Bone Phosphate	Manufacturer's sample	Claimed Found
3224	Tuscarora Fruit and Potato	New Buffalo	Claimed Found

1912, expressed in parts per one hundred.—Con.

Nitrogen.	Phosphoric Acid. Total.	Phosphoric Acid. Insoluble.	Phosphoric Acid. Available.	Potash.	Valuation.
3.75 3.96	23 21.05	....	....	....	$31.75 33.33
....	.... 12.10	1 1.15	10 10.95	2 2.05	11.80 12.80
2.47 **1.91**	.... 10.90	1 2.49	8 8.41	5 4.88	21.70 **20.60**
2.47 **2.31**	.... 10.45	1 2.37	8 8.08	5 5.46	21.70 22.17
0.82 1.07	.... 10.65	1 1.27	8 9.38	3 3.02	14.02 16.42
1.65 1.70	.... 11.60	1 2.32	8 9.28	2 2.28	16.07 18.31
1.65 1.63	.... 11.10	1 2.72	8 8.38	2 2.18	16.07 17.23
0.82 0.95	.... 11.55	1 2.00	8 9.55	4 4.07	14.92 17.39
....	....	....	....	50 54.11	45.00 48.70
....	.... 15.30	0.50 0.25	14 15.05	....	14.00 15.05
0.82 1.04	.... 8.00	0.50 1.00	7 7.00	1 1.25	11.02 12.23
....	.... 12.20	0.50 2.10	10 10.10	2 2.12	11.80 12.01
1.65 1.74	.... 10.35	0.50 2.12	8 8.23	5 5.30	18.57 20.04
....	.... 11.10	0.50 0.85	10 10.25	....	10.00 10.25
1.65 1.59	.... 9.90	0.50 1.42	8 8.48	10 10.71	23.07 24.35

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	Tuscarora Fertilizer Co., Chicago, Ill.—*Con.*		
5268	Tuscarora Garden	Port Huron	Claimed. Found.
5225	Tuscarora Standard	New Buffalo	Claimed. Found.
5226	Wolverine Special	New Buffalo	Claimed. Found.
	The Wuichet Fertilizer Co., Dayton, Ohio.		
5302	Buckeye Phosphate	Manufacturer's sample	Claimed. Found.
3168	Gem	Saginaw	Claimed. Found.
5329	Gem	Pewamo	Claimed. Found.
3169	Miami	Mason	Claimed. Found.
3170	Onion and Truck	Saginaw	Claimed. Found.
5330	Onion and Truck	Pewamo	Claimed. Found.
3171	Potash Special	Mason	Claimed. Found.
5331	Potash Special	Mason	Claimed. Found.
5227	Ruby	Ashley	Claimed. Found.
5236	Spot Cash Fertilizer	Howell	Claimed. Found.
3172	Superior Pure Raw Bone	Mason	Claimed. Found.

1912, expressed in parts per one hundred.—Con.

Nitrogen.	Phosphoric Acid. Total.	Insoluble.	Available.	Potash.	Valuation.
2.88 3.02	.... 10.80	0.50 1.97	8 8.83	4 4.10	$22.07 21.06
1.65 1.71	.... 11.35	0.50 2.60	8 8.75	2 2.50	15.87 18.15
0.82 1.02	.... 12.10	0.50 2.02	8 10.08	4 4.69	14.72 18.74
....	.... 21.40	1 0.52	16 20.88	....	16.00 20.88
0.80 0.97	.... 12.80	1 2.05	8 10.75	5 **3.84**	15.75 18.48
0.80 0.87	.... 11.45	1 2.00	8 9.45	5 5.07	15.75 17.91
0.80 0.83	.... 13.65	1 3.75	9 9.90	3 3.15	14.95 17.19
1.60 1.92	.... 12.90	1 1.95	8 10.95	8 **7.28**	21.30 25.11
1.60 **1.44**	.... 13.20	1 3.30	8 9.90	8 **7.24**	21.50 22.87
0.80 0.70	.... 9.25	1 1.37	5 7.88	11 **9.33**	18.15 19.32
0.80 0.78	.... 7.40	1 1.14	5 6.26	11 12.45	18.15 20.71
0.80 1.05	.... 11.90	1 2.10	9 9.50	1 1.45	13.15 15.51
1.60 **1.40**	.... 14.75	1 4.80	9 9.95	2 2.36	16.90 18.98
3.20 3.48	20 22.10	....	....	....	27.39 30.08

SEED ANALYSES FOR 1911 AND 1912.

Bulletin No. 270.

BY ERNST A. BESSEY, PROFESSOR OF BOTANY.

The act regulating the sale of agricultural seeds (No. 289 of the Public Acts of 1909) is out of print and cannot be obtained except in complete volumes of the Public Acts of 1909. It is accordingly given in full as follows[1]:

AN ACT TO REGULATE THE SALE OF AGRICULTURAL SEEDS AND FRUIT TREES.

The People of the State of Michigan enact:

SECTION 1. Every lot of seeds of agricultural plants whether in bulk or in package, containing one pound or more, except sweet corn, beans, peas, cucumbers, melons, pumpkins, squashes, but including all cereals, grains, clover, alfalfa and garden plants which are sold, offered or exposed for sale for seed by any person or persons in Michigan, shall conform to the standards of purity and freedom from foreign matter specified in sections six and seven of this act, and all fruit trees, including apple, pear, peach, cherry and plum, shall be true to name for which they are sold: *Provided*, That mixtures of seeds, grains and cereals may be sold as such when the percentage of the various constituents is stated in a written or printed guarantee, which must accompany each package or lot sold or offered for sale.

SEC. 2. Dealers may base their guarantee on tests conducted by themselves or their agents: *Provided*, That such tests comply with methods prescribed by the director of the experiment station.

SEC. 3. The said director may take in person or by deputy, a sample of the seeds, grains or cereals which are mentioned in section one of this act, not exceeding four ounces in weight, for said analysis, from any lot or package of agricultural seeds which may be in the possession of any grower, importer, agent or dealer in the State. Such samples shall be taken in the presence of the person who sold or offered or exposed or had them in his possession for sale, or they shall be taken in the presence of two impartial witnesses, and in accordance with the rules for the seed testing prescribed by the director of the experiment station, and shall be enclosed in a sealed package, together with a certified statement of the person taking the sample, which statement shall include the name and address of the person who sold or offered, exposed or had in his possession for sale, the seeds from which

[1]The spelling and punctuation of the original act are followed, although there were some errors in each.

the said sample was taken, the manner in which the receptacle, package, sack or bag was marked, and the section or sections of the act in violation of which the said seeds were found or suspected to be sold or offered, exposed or had in possession for sale.

SEC. 4. Any person charged with the enforcement of this act may enter upon any premises to make any examination of any seeds, receptacles, packages, sacks or bags of seed, with respect to which he has reason to suspect or believe that any provision of this act is being violated, whether such seeds, receptacles, packages, sacks or bags of seeds are on the premises of the owner, or on other premises, or in the possession of a railway or steamship company, and may take any samples of the said seeds from any receptacle, package, sack or bag, for which samples the owner of the seed shall be paid in accordance with the amount of the seed thus taken at its current value; and any person who obstructs or refuses to permit the making of any such examination, or the taking of any such samples of seeds, shall upon conviction be liable to a penalty not exceeding two hundred dollars and not less than twenty-five dollars, together with the costs of the prosecution, and in default of payment of the said penalty and costs, shall be liable to imprisonment for a term not exceeding six months, unless the said penalty and the costs are sooner paid.

SEC. 5. Said director shall analyze or cause to be analyzed such samples of agricultural seeds as are sold or offered for sale under the provisions of this act, upon complaint or request of purchaser, and may make such further analyses as are necessary to determine the accuracy of guarantees.

SEC. 6. No person shall sell or offer, expose or have in his possession for sale for the purpose of seeding, any seeds or cereals, grasses, clovers or forage plants containing more than two per cent of any one or more of the following weeds: Quack grass, Agropyron repens Beauv.; charlock, Brassica arvensis B. S. P.; black mustard, Brassica nigra Kock; Indian mustard, Brassica juncea; false flax, Camelina sativa Crantz; Canada thistle, Carduus arvensis Robs; chicory, Cichorium intybus L.; oxeye daisy, Chrysanthemum Laucanthemum L.; dodder, Cuscuta; wild carrot, Daucus carota L.; orange hawkweed, Hieracium aurantiacum L.; toadflax, butter and eggs, Linaria linaria Karst; narrow-leaved plantain, Plantago lanceolata L.; Rugel's plantain, Plantago Rugelii Dec.; night flowering catchfly, Silene noctiflora L.; penny-cress, Thlaspi arvensis L.

SEC. 7. Seeds sold or offered for sale shall not contain adulteration of more than five per cent of other distinguishable seed, sand, crushed rock or any other materials to be found mixed with agricultural seed, and considered by the Director of the State Experiment Station to be objectionable as any of those named in section six: *Provided*, That sections six and seven shall apply only when in the judgment of the Director of the Experiment Station the said lot of seeds in question has been wilfully adulterated or was when harvested too foul ever to be made fit for seeding purposes, or that the same is not as clean as it is commercially practicable to make the same by means of modern appliances.

SEC. 8. The results of all tests of seeds made by said director shall be published by him in the bulletins or reports of the experiment station, together with the names of the persons from whom the samples of seeds were obtained.

SEC. 9. Whoever deliberately or for gain, sells or exposes for sale or for distribution in this State any agricultural seeds without complying with the requirements of this act, or whoever violates any other section or part of this act shall, upon conviction, be punished by a fine of not less than twenty-five dollars and not to exceed two hundred dollars, or in default of said fine and costs, by imprisonment for a term not exceeding six months in the county jail, unless the said fine and costs are sooner paid.

SEC. 10. The provisions of this act shall not apply to any person growing or selling cereals and other seeds for food, nor to seed that is held in storage for the purpose of being re-cleaned, and which has not been offered, exposed or held in possession for sale for the purpose of seeding, nor to farmers selling to each other when no representation is made as to its purity.

SEC. 11. All suits for the enforcement of penalties under the provisions of this act shall be brought in the name of the people of the State of Michigan, and any violation shall be deemed a misdemeanor and tried in the same manner as other misdemeanors are tried.

SEC. 12. The necessary expense incurred in carrying out the provisions of this act shall be paid by warrant of the Auditor General drawn upon the State Treasurer. An itemized bill of necessary expenses shall be made and certified to by the director of said experiment station as herein provided, at the rate of five dollars per day and necessary traveling expenses for the time actually spent in performing the duties herein required, but the total amount shall in no one year exceed the sum of one thousand dollars.

SEC. 13. All acts or parts of acts inconsistent with this act are hereby repealed.

Approved June 2, 1909.

Complying with this act, the Director of the Experiment Station deputized Mr. F. S. Dunks in 1911 and Mr. M. T. Munn in 1912 to collect samples of seeds offered for sale and had these samples so collected analyzed under the immediate supervision of the Professor of Botany. The present bulletin contains a discussion of the results of these analyses together with recommendations for the improvement of the law regarding the purity of agricultural seeds.[1]

In the year 1911, the seed inspector, Mr. Dunks, collected 444 samples which will be referred to hereafter as the official samples of 1911 to distinguish them from the 303 unofficial samples sent in voluntarily by various persons who wished information as to the purity of the samples sent. In 1912 there were but 160 official samples but the number of unofficial samples up to October 1st had reached 309.

Table I shows the number of violations of this law in 1911 and 1912

[1]In view of the fact that no samples of seeds were taken upon complaint or request of purchaser in accordance with section five the following account does not give names of seed dealers samples of whose seed were examined.

in respect to presence of over two per cent of noxious weeds (Section 6), a total amount of foreign seed over five per cent (Section 7), total foreign matter over five per cent (Section 7), inert matter over five per cent (Section 7) and the proportion of ingredients of mixtures not shown (Section 1).

TABLE I.—SAMPLES OF SEEDS VIOLATING THE PURE SEED LAW.

Samples.	No. of samples.	Noxious seeds two per cent or over.		Total foreign seed five per cent or over.		Total foreign matter five per cent or over.		Inert matter five per cent or over.		No. of mixtures.	Mixtures with per cent of ingredients not given.	
		No.	Per cent.	No.	Per cent.	No.	Per cent.	No.	Per cent.		No.	Per cent of total mixtures
Official 1911	444	38	8.3	100	22.5	246	55.4	139	31.3	44	42	94.6
Official 1912	160	12	7.5	23	14.4	78	48.7	40	25 0	11	11	100
Unofficial 1911	303	6	2.0	13	4.3	122	40.2	96	31.7	....	....	....
Unofficial 1912	309	5	1.6	30	9.7	109	35 2	75	24 3	....	....	....

TABLE II.—OCCURRENCE OF SEEDS OF NOXIOUS WEEDS.

Name of weed.	Number of samples in which these seeds appear.								Number of samples in which these seeds appear two per cent or over.							
	Official 1911.		Official 1912.		Unofficial 1911.		Unofficial 1912.		Official 1911.		Official 1912.		Unofficial 1911.		Unofficial 1912.	
	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
Agropyron repens—Quack grass	0	0	0	0	1	.3	2	.6	0	0	0	0	0	0	1	.3
Brassica arvensis—Charlock	4	.9	5	3.1	1	.3	9	2.9	1	.2	0	0	0	0	0	0
Brassica juncea—Indian mustard	3	.7	0	0	3	1.0	6	1.9	0	0	0	0	0	0	0	0
Brassica nigra—Black mustard	6	1.4	0	0	7	2.3	4	1.3	0	0	0	0	0	0	1	.3
Camelina sativa—False flax	8	1.8	0	0	2	.7	1	.3	0	0	0	0	0	0	0	0
Carduus arvensis—Canada thistle	22	5.0	11	7	6	2.0	6	1.9	0	0	0	0	0	0	0	0
Cichorium intybus—Wild Chicory	4	.9	1	.6	7	2.3	9	2.9	0	0	0	0	0	0	0	0
Chrysanthemum leucanthemum—Ox-eye daisy	2	.4	5	3 1	1	.3	4	1.3	0	0	0	0	0	0	0	0
Cuscuta sp.—Dodder	7	1.6	7	4 4	12	4	17	5.5	0	0	0	0	0	0	0	0
Daucus carota—Wild carrot	6	1.4	2	1.2	3	1	1	.3	0	0	0	0	0	0	0	0
Hieracium aurantiacum—Orange Hawkweed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Linaria linaria—Butter and eggs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago lanceolata—Rib-grass or Buckhorn	161	36.3	69	43 1	43	14.2	60	19.4	18	4 1	9	5 6	3	1	2	.6
Plantago rugelii—Rugel's Plantain	135	30.4	48	30 0	40	13.2	27	8.7	8	1.8	2	1.2	3	1	0	0
Silene noctiflora—Night-flowering Catchfly	51	11.5	8	5.0	6	2	11	3 6	2	.4	0	0	0	0	0	0
Thlaspi arvense—Penny cress	0	0	1	0.6	0	0	0	0	0	0	0	0	0	0	0	0
Total number of samples each year	444		160		303		309		....							
Total appearance of noxious seeds	409		147		132		157		29		11		6		4	

The unofficial samples of mixtures lacked information as to whether the proportions of the ingredients were given so that they were omitted from the column concerning the mixtures.

Table II shows the number and per cent of samples in which any of the sixteen kinds of noxious weeds appeared together with the number and per cent in which any one appeared in illegal amount (two per cent or over).

The marked difference in the relative frequency of noxious seeds in the official and unofficial samples is undoubtedly due to the fact that the seed inspector collected mostly those samples that appeared to be likely to be in violation of the law while the unofficial samples largely represent the general run of seeds sold in the state. A similar difference may be see in Table I in the amount of foreign seed. On the other hand in each year the per cent of samples with five per cent or over of inert matter is the same.

The inert matter in the official samples of 1911 averaged 5.5%, ranging from 0 to 83.1%; in the official samples 1912, 7.7% ranging from 0 to 81%; in the unofficial samples 1911, 4.3% ranging from 0 to 48.1%, and unofficial samples 1912, 3.6% ranging from 0 to 60%. The highest amount of noxious weed seed and of total foreign seed were respectively in the official samples 1911, 20.3% and 36.5%; in the official samples 1912, 11.4% and 19.5%; in the unofficial samples 1911, 5.1% and 20% and in the unofficial samples 1912, 18.6% and 95%.

A study of Table II shows that of the sixteen kinds of seeds listed in section six of the pure seed act, two have not appeared in any of the 1216 samples examined, viz: *Hieracium aurantiacum*, Orange Hawkweed and *Linaria linaria*, Butter and Eggs, while one other *Thlaspi arvense*, Penny cress, appeared in but one sample. Of the others, *Plantago lanceolata*, Buckhorn or Ribgrass, *Plantago rugelii*, Rugel's Plantain, *Silene noctiflora*, Night Flowering catchfly, *Carduus arvensis*, Canada thistle and the various kinds of *Cuscuta*, Dodder, were fairly frequent in the order given. Probably the large number of samples containing buckhorn and Rugel's plantain among the official samples is due to the fact that red clover seed in which these are probably the most frequent contaminations made up a very large proportion (42% in 1911 and 45% in 1912) of the samples. The absence or small number of samples in which some of the noxious seeds appeared is due in some cases e. g. penny cress and false flax, to the comparative rarity of these weeds in the state. In the case of orange hawkweed which is now quite widely distributed in the northern part of the lower peninsula, the smallness and lightness of the seed exclude it from being present as a contamination in other seeds while the lightness of the seed of the too common butter and eggs would prevent it remaining in any seed during its cleaning. Still others e. g. quack grass and the mustards, would probably have been found much more abundantly had more samples of small grain and some of the grass seeds (e. g. brome grass, meadow oat grass, etc.) been examined.

In order that these noxious weeds should be present in quantities sufficient to be illegal, i. e. two per cent, the actual number of such seeds allowed would be immense in some cases. This is shown by the following table (Table III) in which are shown the numbers of seeds of each of the sixteen noxious kinds that would be present in a pound in which these seeds are present to the amount of two per cent.

TABLE III.—NUMBER OF NOXIOUS SEEDS PER POUND WHEN PRESENT TO THE AMOUNT OF TWO PER CENT BY WEIGHT.

Name of seed.	Numbers in pound at 2%.
Agropyron repens, Quack grass	2,193
Brassica arvensis, Charlock	1,450
Brassica juncea, Indian mustard	6,440
Brassica nigra, Black mustard	5,931
Camelina sativa, False flax	4,510
Carduus arvensis, Canada thistle	10,878
Cichorium intybus, Chicory	7,382
Chrysanthemum leucanthemum, Ox-eye Daisy	32,428
Cuscuta sp., Dodder[1]	12,953
Daucus carota, Wild carrot	10,283
Hieracium aurantiacum, Orange Hawkweed	87,300
Linaria linaria, Butter and Eggs	72,640
Plantago lanceolata, Buckhorn	11,209
Plantago rugelii, Rugel's Plantain	16,509
Silene noctiflora, Night-flowering Catchfly	9,080
Thlaspi arvense, Penny cress	10,771

[1]The species was Cuscuta arvensis, ield dodder.

It is thus apparent that without being in violation of the law, it would be possible for a sample of seed to contain in one pound up to 12,953 seeds of field dodder (*Cuscuta arvensis*) or 11,209 seeds of buckhorn (*Plantago lanceolata*) or 87,300 seeds of orange hawkweed (*Hieracium aurantiacum*) etc. Fortunately such could never be the case in this last mentioned seed owing to its lightness and the ease with which it could be fanned out. Actually, however, samples were collected in 1911 and 1912 that contained 1.5% by weight of clover dodder, i. e. about 20,000 seeds per pound and 10.1% buckhorn i. e. about 56,000 seeds per pound and many samples contained but little less than two per cent of the latter.

Turning now to the different kinds of seeds examined, we find that alfalfa and red (or June) clover (including its various forms such as mammoth and medium clover) made up the majority of the samples analyzed. Alfalfa is a comparatively new crop in Michigan and hence has been the subject of unusual interest on the part of the farmers of the state. This is apparent from the fact that in 1911 and 1912 respectively, the samples of alfalfa made up 61.7 and 55.7 per cent of the unofficial samples i. e. those sent in voluntarily, with red clover which is much more extensively grown in the state than alfalfa, making up only 17.2 and 13.6 per cent respectively. Probably the difference is largely due to the fact that the average farmer grows his own red clover seed and so does not usually think it worth while to have it tested, while with a new crop like alfalfa, with unknown seeds and from dealers whose reliability is unknown, he feels the need of having the seed examined.

In Table IV is shown by numbers and per cent, the distribution of seeds of the sixteen kinds of noxious weeds in the samples of alfalfa, alsike clover, red clover, white clover, timothy, winter vetch, lawn mixtures and all others, in the official and unofficial samples of 1911 and 1912. Table V shows similarly the distribution in the same kinds of commercial seed of all the recognized kinds of weed seeds found in them aside from the sixteen kinds of noxious weeds.

TABLE IV—OCCURRENCE OF SEED OF NOXIOUS

Kind of seed.		Commercial seed.											
		Alfalfa.				Alsike clover.				Red clover.			
		Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.
Number of samples		51	27	187	172	88	26	10	18	189	72	52	42
Agropyron repens—Quack grass	No.				1								
	Pct				.6								
Brassica arvensis—Charlock	No.		1	1	8					2			1
	Pct		3.7	.5	4.6					1.1			2.4
Brassica juncea—Indian mustard	No.	2		3	5								
	Pct	3.9		1.6	2.8								
Brassica nigra—Black mustard	No.	3		5	5					2			
	Pct	5.9		2.7	2.8					1.1			
Camelina sativa—False flax	No.			1		5						1	1
	Pct			.5		5.7						1.9	2.4
Carduus arvensis—Canada thistle	No.			1		7	3	1	1	7	3	1	2
	Pct			.5		8	11.5	10	5.5	3.7	4.1	.5	4.8
Cichorium intybus—Chicory	No.	1		7	8					2	1		1
	Pct	2		3.7	4.6					1.1	1.4		2.4
Chrysanthemum leucanthemum—Oxeye daisy	No.				1		1		1				
	Pct				.6		3.8		5.5				
Cuscuta—Dodder	No.	4	1	10	16					3	2	2	1
	Pct	7.8	3.7	5.3	9.3					1.6	2.8	3.8	2.4
Daucus carota—Wild carrot	No.									6	1	2	
	Pct									3.2	1.4	3.8	
Hieracium aurantiacum—Orange hawkweed	No.												
	Pct												
Linaria linaria—Butter and eggs	No.												
	Pct												
Plantago lanceolata—Buckhorn or Rib-grass	No.	5	3	8	12	12	4	1	4	123	52	30	32
	Pct	9.8	11.1	4.3	7	13.6	15.4	10	22.2	65.1	72.2	57.7	76.2
Plantago rugelii—Rugel's Plantain	No.	3		7		8	2			82	35	26	16
	Pct	5.9		3.7		9.1	7.7			43.4	48.6	50	38.1
Silene noctiflora—Night-flowering Catchfly	No.	2	1		3	33	3	2	3	6	3	3	2
	Pct	3.9	3.7		1.7	37.5	11.5	20	16.7	3.2	4.1	5.8	4.8
Thlaspi arvense—Penny cress	No.												
	Pct												

WEEDS IN VARIOUS KINDS OF COMMERCIAL SEEDS.

Commercial seed.																			
White clover.				*Winter vetch.				Timothy grass.				Lawn mixtures.				All other seeds.			
Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.
13	4	0	2	0	1	17	20	26	6	15	27	24	11	1	4	53	13	17	24
											1							1	1
											3.7							5.9	4.2
												2	4						
												8.3	36.4						
																1			
																1.9			
																1		2	1
																1.9		11.8	4.2
												2							
												8.3							
	1								1		2	5	3	1	1	3		2	
	25								16.7		7.4	20.8	27.3	25	25	5.7		11.8	
																1			
																1.9			
										1	1	1	4						2
										6.7	3.7	4.1	36.4						8.3
	1												3						
	25												27.3						
	1												1						1
	25												9.1						4.2
6	3		1					1	1		1	4	7	1	3	8		3	[illegible]
46.1	75		50					3.8	16.7		3.7	16.7	63.6	25	75	15.1		17.7	25
5			1					13	1	2	2	13	8	2	1	12		2	6
38.5			50					50	16.7	13.3	7.4	54.2	72.7	50	25	22.6		11.8	25
6								1					1			3		1	2
46.1								3.8					9.1			5.7		5.9	8.3
	1																		
	25																		

*No Noxious Seeds found.

TABLE V.—OCCURRENCE OF WEED SEEDS

Names of weeds.		Commercial seed. Alfalfa. Official, 1911.	Alfalfa. Official, 1912.	Alfalfa. Unofficial, 1911.	Alfalfa. Unofficial, 1912.	Alsike clover. Official, 1911.	Alsike clover. Official, 1912.	Alsike clover. Unofficial, 1911.	Alsike clover. Unofficial, 1912.	Red clover. Official, 1911.	Red clover. Official, 1912.	Red clover. Unofficial, 1911.	Red clover. Unofficial, 1912.
Number of samples		51	27	187	172	88	26	10	18	189	72	52	42
Abutilon theophrasti—Velvet leaf	No.												
	Pct.												
Achillea millefolium—Yarrow	No.				1								
	Pct.				.6								
Agrostemma githago—Corn-cockle	No.												
	Pct.												
Agrostis alba—Redtop grass	No.			1		1							
	Pct.			.5		1.1							
Alsine media—Chickweed	No.						1	1	2			1	1
	Pct.						3.8	10	11.1			1.9	2.4
[1]Alyssum alyssoides—Yellow alyssum	No.				1								
	Pct.				.6								
Amaranthus blitoides—Prostrate Amaranth	No.		1	2	4						1	1	
	Pct.		3.8	1.1	2.3						1.4	1.9	
Amaranthus graecizans—Tumbleweed	No.		2	4	7	2	2	1			8		2
	Pct.		7.4	2.1	4.1	2.3	7.7	10			11.1		4.8
Amaranthus hybridus—Slender pigweed	No.	1		1									
	Pct.	2		.5									
Amaranthus retroflexus—Rough pigweed	No.			10	8					4		6	4
	Pct.			5.3	4.6					2.1		11.5	9.5
Ambrosia artemisiifolia—Ragweed	No.	1		11	1					16	10	20	3
	Pct.	2		5.9	.6					8.5	13.9	38.4	7.1
Amsinckia lycopsoides	No.												
	Pct.												
Anthemis arvensis—Corn camomile	No.					1							
	Pct.					1.1							
Anthemis cotula—Mayweed	No.			2		3			1	1	3	6	3
	Pct.			1.1		3.4			5.6	.5	4.2	11.5	7.1
Arctium minus—Burdock	No.			3	2								
	Pct.			1.6	1.2								
Arenaria serpyllifolia—Thyme-leaved sandwort	No.					2						1	
	Pct.					2.3						1.9	
Atriplex patula—Spreading orache	No.	4	3	14	33								
	Pct.	7.8	11.1	7.4	19.2								
Avena fatua—Wild oats	No.												
	Pct.												
Avena sativa—Oats	No.			1		1							
	Pct.			.5		1.1							
Berteroa incana—Hoary Alyssum	No.			1	1								
	Pct.			.5	.6								
Bidens sp.—Stick-tight	No.												
	Pct.												
Brassica campestris—Rutabaga	No.												
	Pct.												
Brassica oleracea—Cabbage	No.												
	Pct.												
Bromus secalinus—Chess	No.	1											
	Pct.	2											
Bromus sterilis—Barren Brome grass	No.												
	Pct.												
Bursa bursa-pastoris—Shepherd's purse	No.						1		2	1			
	Pct.						3.8		11.1	.5			
Camelina microcarpa—Small-seeded false flax	No.												
	Pct.												
Cannabis sativa—Hemp	No.												
	Pct.												
[illegible]	No.												
	Pct.												
[illegible]	No.		1	1	5								
	Pct.		3.7	.5	2.9								
Centaurea solstitialis[2]—Star thistle	No.				8								
	Pct.				4.6								

[1] It is possible that this may be false identification of Eruca sativa.

[2] It is possible that some, if not all, of the seeds credited to Centaurea solstitialis may be really C. [illegible]

OTHER THAN NOXIOUS IN COMMERCIAL SEED.

Commercial seed.																			
White clover.				Winter vetch.				Timothy grass.				Lawn mixture.				All other seeds.			
Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.
13	4	0	2	0	1	17	20	26	6	15	27	24	11	4	4	53	13	17	21
																		1 5.9	
											1 3.7								
					1 100	14 82.4	18 90												
																			1 4.2
											1 3.7							1 5.9	1 4.2
													3 27						
	1 25									1 6.7	1 3.7					1 1.9			1 4.2
										2 13.3	1 3.7						1 7.7	2 11.8	1 4.2
																1 1.9		1 5.9	1 4.2
							1 .5												
	1 25																		
1 7.7												3 12.5			1 25	4 7.6		2 11.8	
2 15.4			1 50								1 3.7	1 4.2				1 1.9			
																1 1.9			1 4.2
																1 1.9			2 8.3
						1 5.9													
																1 1.9			
																1 1.9			
																1 1.9		1 5.9	1 4.2
																		1 5.9	
1 7.7															1 25	2 3.8			
											1 3.7								
						1 5.9													
											1 3.7								1 4.2

TABLE V.—

Names of weeds.		Commercial seed. Alfalfa. Official, 1911.	Alfalfa. Official, 1912.	Alfalfa. Unofficial, 1911.	Alfalfa. Unofficial, 1912.	Alsike clover. Official, 1911.	Alsike clover. Official, 1912.	Alsike clover. Unofficial, 1911.	Alsike clover. Unofficial, 1912.	Red clover. Official, 1911.	Red clover. Official, 1912.	Red clover. Unofficial, 1911.	Red clover. Unofficial, 1912.
Centaurea solstitialis—[2]Star thistle	No.	1		3									
	Pct	2		1.6									
Cerastium vulgatum—Mouse-ear chickweed	No.					9	4	1	2	1		1	1
	Pct					10.2	15.4	10	11.1	.5		1.9	2.4
Chaetochloa glauca—Yellow Foxtail or Pigeon grass	No.			7	4	1				1	4	6	2
	Pct			3.7	2.3	1.1				.5	5.5	11.5	4.8
Chaetochloa viridis—Green foxtail or Pigeon grass	No.	10	12	86	72	1	1	1		52	44	27	27
	Pct	19.6	44.4	46	41.9	1.1	3.7	10		27.5	61.1	51.9	64.3
Chamaenerion angustifolium—Fireweed	No.												
	Pct.												
Chelidonium majus—Celandine	No.				1	1							
	Pct.				.6	1.1							
Chenopodium album—Lamb's Quarters	No.	20	9	64	41		1	1		16	18	19	5
	Pct	39.2	33.3	34.2	25.6		3.8	10		8.5	25	36.5	11.9
Chenopodium hybridum—Maple-leaved goosefoot	No.			2									
	Pct.			1.1									
Cirsium lanceolatum—Bull thistle	No.			2						1			
	Pct.			1.1						.5			
Conium maculatum—Poison hemlock	No.												
	Pct.												
[1]Conringia orientalis—Hare's ear	No.				1								
	Pct.				.6								
Convolvulus arvensis—Field Bindweed	No.				2								
	Pct.				1.2								
Cycloloma atriplicifolium—Winged pigweed	No.			1									
	Pct.			.5									
Dipsacus sylvestris—Teasel	No.											1	
	Pct.											1.9	
Echinochloa crus-galli—Barnyard grass	No.			3	10							2	2
	Pct.			1.6	5.8							3.8	4.8
Echinochloa frumentacea—Japanese barnyard millet	No.			1									
	Pct.			.5									
Eleocharis ovata—Ovoid Spike-rush	No.					1	1						
	Pct.					1.1	3.7						
Eragrostis sp.	No.												
	Pct.												
[3]Eruca sativa—Roquette	No.				1								
	Pct.				.6								
Erysimum cheiranthoides—Worm-seed mustard	No.					1							
	Pct.					1.1							
Euphorbia sp.—Spurge	No.			2	1				2		1		2
	Pct.			1.1	.6				11.1		1.4		4.8
Galium aparine—Cleavers	No.												
	Pct												
Gaura parviflora—Small-flowered Gaura	No.												
	Pct.												
Geranium dissectum—Cut-leaved Crane's bill	No.										1		
	Pct.										1.4		
Grindelia squarrosa—Gum-weed	No.			5	2								
	Pct.			2.7	1.2								
Helianthus sp.—Sunflower	No.			1	3								
	Pct.			.5	1.7								
Hordeum sativum—Barley	No.												
	Pct.												
Hypericum perforatum—St. John's Wort	No.												
	Pct												
Iva xanthifolia—Marsh elder	No.				1								
	Pct				.6								
Lactuca sativa—Lettuce	No.												
	Pct												
Lactuca scariola integrata—Prickly lettuce	No.											2	1
	Pct											3.8	2.4
Lappula lappula—Stick-seed	No.	3		2									
	Pct.	5.9		1.1									
Lens esculenta—Lentil	No.												
	Pct												

[1] It is possible that this may be a false identification of Eruca sativa.

[2] It is possible that some, if not all, of the seeds credited to Centaurea solstitialis may be really C[illegible] [illegible]perls.

[3] See foot note on Alyssum alyssoides and Conringia orientalis.

CONTINUED.

Commercial seed.

White clover.				Winter vetch.				Timothy grass.				Lawn mixture.				All other seeds.			
Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.
												1 4.2							
1 7.7	1 25		1 50									2 8.3	10 91	1 25	2 50	4 7.6		1 5.9	1 4.2
																2 3.8		1 5.9	
									1 16.7		1 3.7		1 9.1			2 3.8	1 7.7	2 11.8	3 12.5
													2 18.2						
								3 11.5		3 20	8 29.6		2 18.2		1 25	3 5.7		2 11.8	5 20.8
																			1 4.2
								1 3.8											
											1 3.7							2 11.8	1 4.2
										1 6.7									
																		1 5.9	
										1 6.7			8 72.8						1 4.2
											2 7.4		1 9.1						
					1 100	10 58.8	7 35												
																			1 4.2
																1 1.9			
												1 4.2				1 1.9			
																1 1.9			
																			1 4.2
					1 100														

TABLE V.—

Names of weeds.		Commercial seed.											
		Alfalfa.				Alsike clover.				Red clover.			
		Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.
Leonurus cardiaca—Motherwort	No.										1		1
	Pct.										1.4		2.4
[4]Lepidium apetalum—Wild Peppergrass	No.												
	Pct.												
Lepidium campestre—Cow cress	No.						1						
	Pct.						1.4						
[4]Lepidium virginicum—Wild Peppergrass	No.					7	9		5	2	3	2	3
	Pct.					8	34.6		27.8	1.1	4.2	3.8	7.1
Linum usitatissimum—Flax	No.												1
	Pct.												2.4
Lithospermum arvense—Corn gromwell	No.												1
	Pct.												2.4
Lolium perenne—Ray grass	No.												
	Pct.												
Malva rotundifolia—Cheeses	No.				4					5	3	5	
	Pct.				2.3					2.6	4.2	9.6	
Malva verticillata—Whorled mallow	No.				1								
	Pct.				.6								
Marrubium vulgare—Horehound	No.	1											
	Pct.	2											
Medicago lupulina—Black medick	No.		1		2			1				2	
	Pct.		3.8		1.2			10				3.8	
Medicago sativa—Alfalfa	No.					2			1				1
	Pct.					2.3			7.6				2.4
Melilotus alba—White sweet clover	No.	1	4	10	23				2				
	Pct.	2	14.8	5.3	13.4				11.1				
Melilotus indica	No.			1									
	Pct.			.5									
Nepeta cataria—Catnip	No.									2	1	2	
	Pct.									1.1	1.4	3.8	
Onagra biennis—Evening Primrose	No.					2							
	Pct.					2.3							
Panicum capillare—Tickle grass	No.		3		3		2	1			5		
	Pct.		11.1		1.7		7.7	10			6.9		
Panicum miliaceum—Broomcorn millet	No.												
	Pct.												
Panicum virgatum—Switch grass	No.	1		2	2							1	1
	Pct.	2		1.1	1.2							1.9	2.4
Paspalum sp.	No.												1
	Pct.												2.4
Pennisetum—Pearl millet	No.				1								
	Pct.				.6								
Phleum pratense—Timothy grass	No.	2	4	20	4	50	18	9	13	43	24	16	11
	Pct.	3.9	14.8	10.7	2.3	56.8	69.2	90	72.2	22.8	33.3	30.8	26.2
Pisum sp.—Pea	No.												
	Pct.												
Plantago aristata—Bracted plantain	No.									5	6	2	1
	Pct.									2.6	8.3	3.8	2.4
Plantago major—Common plantain	No.	1				1				3	1	8	
	Pct.	2				1.1				1.6	2.4	15.4	
Poa compressa—Canadian bluegrass	No.												
	Pct.												
Poa pratensis—Kentucky bluegrass	No.						4	1		2	1	1	2
	Pct.						15.4	10		1.1	1.4	1.9	4.8
Polygonum aviculare—Knot grass	No.			2								1	
	Pct.			1.1								1.9	
Polygonum convolvulus—Wild buckwheat	No.			1									
	Pct.			.5									
Polygonum erectum—Erect knotweed	No.			2	1								
	Pct.			1.1	.6								
Polygonum hydropiper—Smartweed	No.				1	1						1	
	Pct.				.6	1.1						1.9	
Polygonum lapathifolium—Dock-leaved persicaria	No.												2
	Pct.												4.8
Polygonum pennsylvanicum	No.										1	2	
	Pct.										1.4	3.8	

[4] Probably these have been confused with each other in many cases.

CONTINUED.

Commercial seed.

White clover.				Winter vetch.				Timothy grass.				Lawn mixture.				All other seeds.			
Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.
											8								2
											29 6								8.3
1								4	5	6	6	3	6	1	1	6		2	5
7.7								15.4	83.3	40	22.2	12.5	55	25	25	11.3		11.8	20.8
																			1
																			4 2
												1							
												4.2							
																1		1	
																1.9		5.9	
										2		2							
										13.3		8.3							
																			1
																			4.2
						2													
						11.8													
2	1		1													6			
15.4	25		50													11.3			
							1												
							5												
												1		1		1			
												4.2		25		1.9			
1										1		2		1	2	2			
7.7										6.7		8.3		25	50	3.8			
											2								1
											7.4								4.2
									2	3	3					3		1	2
									33.3	20	11.1					5.7		5.9	8.3
1																			
7.7																			
																			1
																			4.2
1											1								
7.7											3.7								
												1		2		5			1
												4.2		50		9.4			4.2
																1		4	
																1.9		23.5	

TABLE V.—

Names of weeds.		Commercial seed.											
		Alfalfa.				Alsike clover.				Red clover.			
		Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.
Polygonum persicaria—Lady's thumb	No.				1		1			5	19	6	7
	Pct				.6		3.8			2.6	26.4	11.5	16.7
Potentilla canadensis	No.												
	Pct.												
Potentilla monspeliensis—Rough Cinquefoil	No.				1	2		1	2		2	3	
	Pct.				.6	2.3		10	11.1		2.8	5.8	
Prunella vulgaris—Self-heal	No.												
	Pct.												
Ranunculus acris—Buttercup	No.												
	Pct.												
Raphanus sativus—Radish	No.			1									
	Pct			.5									
Rudbeckia hirta—Black-eyed Susan	No.			3			1						
	Pct.			1.6			3.8						
Rumex acetosa—Sorrel	No.				7		3	1	3	1	4	2	7
	Pct				4.1		11.5	10	16.7	.5	5.5	3.8	16.7
Rumex acetosella—Field sorrel	No.	1	1	3	3	39	19	4	11	24	21	9	7
	Pct	2	3.7	1.6	1.7	44.3	73.1	40	61.1	12.8	29.2	17.3	16.7
Rumex crispus—Yellow dock	No.	1		6	10	8	1	2	1	26	7	14	5
	Pct.	2		3.2	5.8	9.1	3.8	20	5.5	13.8	9.7	26.9	11.9
Rumex obtusifolius—Bitter dock	No.									1		1	
	Pct.									.5		1.9	
Salsola kali tenuifolia—Russian thistle	No.	21	6	51	34			1				1	
	Pct	41.2	22.2	27.3	19.8			10				1.9	
Saponaria officinalis—Bouncing Bet	No.									1			
	Pct									.5			
Scirpus sp.	No.												
	Pct												
Secale cereale—Rye	No.												
	Pct.												
Sida spinosa—Prickly sida	No.											1	
	Pct.											1.9	
Silene antirrhina—Sleepy catchfly	No.										1		
	Pct.										1.4		
Sinapis alba—White mustard	No.			1									
	Pct			.5									
Sisymbrium altissimum—Tumbling mustard	No.							1	1				
	Pct.							10	5.6				
Sisymbrium officinale—Hedge mustard	No.					1							
	Pct					1.1							
Sonchus oleraceus—Sow thistle	No.												
	Pct.												
Spergula arvensis—Spurry	No.												
	Pct.												
Spermoedia clavus—Ergot	No.									1			1
	Pct.									.5			2.4
Syntherisma linearis—Small crabgrass	No.			2	1	1				2	5	9	3
	Pct.			1.1	.6	1.1				1.1	6.9	12.3	7.1
Syntherisma sanguinalis—Large crab grass	No.			2	2				1	1	5	2	2
	Pct			1.1	1.2				5.6	.5	6.9	3.8	4.8
Taraxacum taraxacum—Dandelion	No.												
	Pct.												
Trifolium hybridum—Alsike clover	No.		1	7	11					25	13	16	1
	Pct.		3.7	3.7	6.4					13.2	18.1	30.8	2.4
Trifolium incarnatum—Crimson clover	No.			1									
	Pct			.5									
Trifolium pratense—Red clover	No.	4		23	10	11	8	1	3				
	Pct.	7.8		12.3	5.8	12.5	30.8	10	16.7				
Trifolium procumbens—Low hop clover	No.								1				
	Pct								5.6				
Trifolium repens—White clover	No.			3		9	2	1		7		1	1
	Pct			1.6		10.2	7.7	10		3.7		1.9	2.4
Triticum aestivum—Wheat	No.												
	Pct												
Urtica gracilis—Slender nettle	No.				1								1
	Pct				.6								2.4

CONTINUED.

Commercial seed.

White clover.				Winter vetch.				Timothy grass.				Lawn mixture.				All other seeds.			
Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.
											3					3		3	1
											11.1					5.7		17.6	4.2
												1							
												4.2							
1								6	3	4	2	7	3	2	3	6		2	6
7.7								23.1	50	26.7	7.4	29.2	27	50	75	11.3		11.8	25
													2						
													18.2						
													4						
													36						
																1			
																1.9			
								1			2	2			1				1
								3.8			7.4	8.3			25				4.2
								2			1						1		
								7.7			3.7						7.7		
5	4		2					1	2	4	15	6	5	1	1	12		1	5
38.5	100		100					3.8	33.3	26.7	55.5	25	45.5	25	25	22.6		5.9	20.8
									1		1	3	3		1	2		1	3
									16.7		3.7	12.5	2.7		25	3.8		5.9	12.5
																1			
																1.9			
																			1
																			4.2
						3													1
						17.6													4.2
																		2	
																		11.8	
																1			
																1.9			
													3						
													2.7						
								1				1	1			2			
								3.8				4.2	9.1			3.8			
								1											
								3.8											
																			1
																			4.2
									2										
									18.2										
1	2							7	1	5	7							2	1
7.7	50							26.9	16.7	33.3	25.9							11.8	4.2
1			1					1	1	2	5					1		2	1
7.7			50					3.8	16.7	13.3	18.5					1.9		11.8	4.2
										1						2			1
										6.7						3.8			4.2
					1	3	4				1					1	1	1	1
					100	17.6	20				2.7					1.9	7.7	5.9	4.2
									1	3	2		1						
									16.7	20	7.4		9.1						

TABLE V.—

Names of weeds.		Commercial seed. Alfalfa. Official, 1911.	Alfalfa. Official, 1912.	Alfalfa. Unofficial, 1911.	Alfalfa. Unofficial, 1912.	Alsike clover. Official, 1911.	Alsike clover. Official, 1912.	Alsike clover. Unofficial, 1911.	Alsike clover. Unofficial, 1912.	Red clover. Official, 1911.	Red clover. Official, 1912.	Red clover. Unofficial, 1911.	Red clover. Unofficial, 1912.
Vaccaria vaccaria— Cow-herb	No.												
	Pct.												
Verbascum thapsus— Mullein	No.											2	
	Pct.											3.8	
Verbena hastata— Blue vervain	No.			2						2		2	
	Pct.			1.1						1.1		3.8	
[5]Vicia grandiflora	No.												
	Pct												
[5]Vicia hirsuta	No.												
	Pct.												
[5]Vicia sativa— Spring vetch	No.												
	Pct.												

[5] Several species of Vicia and Lathyrus and other related genera are probably grouped under the heading Vicia sativa. It is only for the unofficial samples of 1912 that V. grandiflora and V. hirsuta are segregated.

CONCLUDED.

Commercial seed.																			
White clover.				Winter vetch.				Timothy grass.				Lawn mixture.				All other seeds.			
Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.	Official, 1911.	Official, 1912.	Unofficial, 1911.	Unofficial, 1912.
.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	5.9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	.....	1
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.9	.....	.....	4.2
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3	.....	.....	.....	.....	.....	.....	.....	.....	1
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	20	.....	.....	.....	.....	.....	.....	.....	.....	4.2
.....	.....	.....	.....	.....	.....	.....	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	1	7	20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	100	41.2	100	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE VI.—SAMPLES OF SEED OF VERY POOR QUALITY

Number	157—Unofficial, 1911.	302—Unofficial, 1911.
Kind of seed.	Alfalfa.	Alfalfa.
Pure seed, per cent	85.2	91.0
Inert matter, per cent	12.7	8.1
Other seed, per cent	2.1	0.9
Noxious seeds		Cuscuta sp.— Small seeded dodder, 0.85%. Cuscuta sp.— Large seeded dodder, 91 per lb.
Total noxious per cent	0	0.85%
Other weed seeds	Salsola kali tenuifolia— Russian thistle, 2%. Grindelia squarrosa— Gum weed, 273 per lb. Chenopodium album— Lamb's quarters, 364 per lb.	Chenopodium album— Lamb's quarters, 182 per lb. Cirsium lanceolatum— Bull thistle, 182 per lb. Lappula lappula— Stickseed, 273 per lb. Amaranthus retroflexus— Rough pigweed, 91 per lb. Polygonum convolvulus— Wild buckwheat, 182 per lb.
Number	161—Official, 1911.	374—Official, 1911.
Kind of seed.	Red clover.	Red clover. (Medium)
Pure seed, per cent	83.9	77.5
Inert matter, per cent	1.4	0.5
Other seed, per cent	14.7	22.0
Noxious seeds		Plantago lanceolata— Buckhorn, 8.1%. Plantago rugelii— Rugel's plantain, 12.2%.
Total noxious, per cent	0	20.3%
Other weed seeds	Chaetochloa viridis— Green foxtail, 14.7%.	Timothy grass 1.7%.

OFFERED FOR SALE IN MICHIGAN 1911 AND 1912.

305—Official, 1911.	336—Official, 1911.	287—Unofficial, 1912.
Alsike clover. 96.6 0.7 2.7	Alsike clover. 70 4 26	Alsike clover. 10 1 89
Silene noctiflora— Night-flowering catchfly, 2 %. Camelina sativa— False flax, trace.		
2 + %	0	0
Miscellaneous weeds, 0.6 %.	Rumex acetosella— Field sorrel, 24.5 %. Miscellaneous, 1.5 %.	Rumex acetosella— Field sorrel, 81. + %. Red clover, 4. + %. Timothy grass, 3.4 %.

104—Official, 1911.	71—Official, 1911.	312—Official, 1911.
Red clover. (Medium) 85.2 3.5 11.3	Red top grass. 80 8 12	Rutabaga. 77.6 3.8 18.6
Plantago lanceolata— Buckhorn, 10.1 %.	Plantago rugelii— Rugel's plantain, trace.	Brassica nigra— Black mustard, 18.6 %.
10.1 %	Trace.	18.6 %
Miscellaneous, 1.2 % = 5,000 seeds per lb.	Timothy grass, 11.8 %. Lepidium virginicum— Pepper grass, trace.	Note.—Probably this was a deliberate adulteration.

TABLE VI.—

Number	443—Official, 1911.	444—Official, 1911.
Kind of seed.	Central Park Lawn Seed.	Standard Lawn Seed.
Pure seed, per cent	15.2	41.4
Inert matter, per cent	83.1	52.5
Other seed, per cent	1.7	6.1
Noxious seeds	Brassica arvensis— Charlock, 227 per lb. Camelina sativa— False flax, 2,043 per lb. Carduus arvensis— — Canada thistle, 908 per lb. Plantago rugelii— Rugel's plantain, 227 per lb.	Plantago rugelii— Rugel's plantain, 4.6 %. Plantago lanceolata— Buckhorn, 453 per lb.
Total noxious, per cent	Trace.	4.6 % +
Other weed seeds	Potentilla monspeliensis— Rough cinquefoil, 3,405 per lb. Rumex crispus— Yellow dock, 908 per lb. Rumex acetosella— Field sorrel, 1,816 per lb. Miscellaneous, 3,178 per lb.	Lepidium virginicum— Pepper grass, 2,265 per lb. Cirsium lanceolatum— Bull thistle, 302 per lb. Potentilla monspeliensis— Rough cinquefoil, 1,510 per lb. Rumex crispus— Yellow dock, 906 per lb. Miscellaneous, 2,265 per lb.
Number	293—Unofficial, 1912.	300—Unofficial, 1912.
Kind of seed.	Timothy grass.	Timothy grass.
Pure seed, per cent	69.8	72.3
Inert matter, per cent	3.2	0.3
Other seed, per cent	27.0	27.4
Noxious seeds	Agropyron repens— Quack grass, 9 %.	Plantago lanceolata— Buckhorn, 0.4 %.
Total noxious, per cent	9 %	0.4 %
Other weed seeds	Wheat, 6.5 %. Lepidium apetalum— Pepper grass, 10.6 %. Miscellaneous, 0.9 %.	Rumex acetosella— Field sorrel, 25.2 %. Rumex crispus— Yellow dock, 0.6 %. Various clovers, 1.2 %.

CONCLUDED.

13—Official, 1911.	142—Official, 1911.	315—Official, 1911.
Timothy and alsike mixed.[1] 59 31 10	Timothy and alsike mixed.[1] 84.9 2.0 13.1	Timothy and alsike mixed.[1] 28.9 50.1 21.0
Chrysanthemum leucanthemum— Ox-eye daisy, 0.35 %. Plantago lanceolata— Buckhorn, 0.4 %. Plantago rugelii— Rugel's plantain, 1.6 %. Silene noctiflora— Night-flowering catchfly, 0.5 %.		Silene noctiflora— Night-flowering catchfly, 2.3 %.
2.85 %	0	2.3 %
Cerastium vulgatum— Mouse-ear chickweed, 1 %. Potentilla monspeliensis— Rough cinquefoil, 20,000 per lb. Anthemis cotula— Mayweed, 7,250 per lb. Lepidium virginicum— Pepper grass, 1,800 per lb. Bursa bursa-pastoris— Shepherd's purse, 1,800 per lb. Miscellaneous, 5+ %.	Rumex acetosella— Field sorrel, 13.1 %.	Cerastium vulgatum— Mouse-ear chickweed, 16.2 %. Potentilla monspeliensis— Rough cinquefoil, 1. %. Bursa bursa-pastoris— Shepherd's purse, 0.3 %. Rumex acetosella— Field sorrel, 0.4 %. Miscellaneous, 0.8 %.
268—Unofficial, 1912.		
Winter vetch.[2] 79.5 1.1 19.4		
0		
Other vetches, mainly Vicia sativa— Spring vetch, 18.5 %. Agrostemma githago— Cockle, 0.7 %. Galium aparine— Cleaver's, 0.1 %. Miscellaneous, 0.1 %.		

[1] These three samples violated the law also in failing to have the proportions stated upon the container.

[2] This is more properly Hairy Vetch but is more generally known in this state as Winter or Sand Vetch.

A study of Table IV shows that certain kinds of weed seeds are distributed without much respect to the kind of seed in which they are found while others are found more especially as contamination of certain kinds. Thus the dodders were more abundant in alfalfa, buckhorn and Rugel's plantain in red clover, night-flowering catchfly in alsike clover. Table V shows that there are certain very commonly occurring weed seeds. These are lamb's quarters (*Chenopodium album*), green foxtail or pigeon grass (*Chaetochloa viridis*), both very common in red clover and alfalfa seed, Russian thistle (*Salsola kali tenuifolia*) and spreading orache (*Atriplex patula*) abundant in alfalfa but almost lacking in the other kinds of seed, field sorrel (*Rumex acetosella*) especially in timothy and alsike but also occurring in red clover, pepper grass (*Lepidium virginicum* and *L. apetalum*) in timothy, ragweed (*Ambrosia artemisiifolia*) in red clover and alfalfa. Red clover is a frequent contamination of alfalfa; timothy is very frequently found in red clover, alfalfa and especially alsike, while alsike is very frequently found in red clover and especially in timothy. The contaminations of hairy (or winter) vetch owing partly to the larger size of the seed, were different from the foregoing. The contaminants are spring vetch (*Vicia sativa*) and a number of other vetches and species of *Lathyrus*. These may be present in large quantities, i. e. often 20 per cent. Nearly every sample has a small amount of cockle (*Agrostemma githago*) and cleavers (*Galium aparine*) while oats, wheat and rye are frequent accidental contaminations.

As would be expected, the seeds found as contaminations are usually those of approximately the same size as the seed in which they are found. When it is otherwise, it is because the seed has not been cleaned or has been carelessly handled after cleaning or that screenings have been used to cheapen it. There is far too much of this carelessly handled seed on the market. To illustrate the quality of some of the lots of seed actually offered for sale in Michigan in 1911 and 1912, there are given above (Table VI) the analyses of a number of the most striking samples. These were mostly obtained of seed dealers in small towns or of farmers who were offering the seed for sale. Sometimes in the case of the dealer, usually in the farmers' case, the poor quality of the seed was not recognized owing to lack of knowledge in this matter. Unfortunately, however, a number of the smaller cities of the state are infested with unscrupulous seed merchants who buy screenings at low prices from some of the large seed firms and mix them with better seed or sell them directly thus introducing low-grade seed into their locality to the detriment of the honest dealers and the great harm of the farmers. Perhaps the worst lots are the packages of lawn grass seed put up by some of the New York state seed firms. They are usually in pasteboard cartons with a picture of a vivid green lawn. They are mostly just under a pound in weight so that they do not violate the letter of the law. They are usually sold for five or ten cents by five and ten cent stores and by department stores. The sale of such trash is greatly to be deplored as it injures the legitimate business of reliable firms. The price alone is enough to show the fraud for with Kentucky Blue grass at twenty-five or thirty cents a pound and white clover at eighteen to twenty cents or over and other grass seeds similarly high priced, it is absurd to suppose that a package of about

a pound of good lawn seed can be sold for five cents or even ten cents. The analyses given above will explain how it can be done.

Tables I, II, IV, V and VI and the discussions of them reveal the fact that weed seeds are abundantly present in the seed sold in Michigan. The importance of this can not be over-emphasized. It is probably not going beyond the actual fact to assert that at least ninety per cent of the weeds that appear on a farm have been introduced as contaminations of the seed sown. This agency for the introduction of weeds is being demonstrated on a large scale right now in Michigan. Alfalfa is a new crop for most farms in Michigan and practically all the seed sown these past two years (the period the writer has had the matter under observation) has come from the West, Montana, Nebraska, Kansas and Utah, mainly. As will be noticed by reference to Table V 20 to 40 per cent of all the samples examined in 1911 and 1912 by the Department of Botany contained seed of Russian thistle. This weed is a native of Southeastern Russia and was introduced twenty or thirty years ago into the West where it is now widespread and a frequent pest of the alfalfa fields as well as elsewhere. During the latter part of summer and early fall in both 1911 and 1912 the writer has received a great many plants of Russian thistle that have appeared in farms in all parts of the state, as new weeds, and the significant fact is that with one exception, they have appeared as weeds in alfalfa fields. The connection is obvious. Similarly *Eruca sativa*, Roquette, has appeared as a weed in a great many alfalfa fields the past two seasons. This is well established as a weed (introduced from Europe) in many of the alfalfa regions of the West. A glance at the tables of seeds will not reveal this in more than two samples. The fact was that, until the specimens of the weed began to be sent for identification, the seed which had appeared frequently in the samples of alfalfa seed examined had been wrongly identified (thus *Alyssum alyssoides* and *Conringia orientalis* of the list were probably in all cases *Eruca sativa*) or had failed to be identified and were placed in the reports among miscellaneous seeds. Having found the weed so abundantly in alfalfa fields, we now are able to recognize its seed in many of the samples previously sent in.

The great prevalence of buckhorn, field sorrel, etc., in fields of red clover and alsike or timothy respectively, corresponds clearly to the abundance of the seeds of these weeds in clover and alsike or timothy seed.

Greatly to be deplored is the too common practice of cutting for hay the part of a clover or timothy field where the stand is fairly pure and cutting for seed the portion of the field where the stand is thin and too weedy to make good hay. It seems absurd that a thinking man could do such a thing but apparently the faith of such a man in the power of a fanning mill to remove weed seeds is immense. It is regretted that it is not the general instead of the exceptional practice of the general farmer to save for seed that portion of the field that is the cleanest. Indeed, common-sense would dictate that a field to be cut for seed should be gone over carefully and all the weeds present pulled or cut. This extra care is well repaid in the freedom of the seed from contamination. Equally blind is the practice of those men who go to a seed dealer and buy his screenings or poor grade seed because it is

cheap, not realizing that such seed is really the dearest seed he can buy, if measured by the amount of pure seed obtained and the time and energy necessary to fight the weeds introduced with the poor seed. An extra dollar or two per bushel for clean clover or alfalfa seed will be a good investment.

There are several points in which the present pure seed law appears faulty, from the standpoint of protection of the buyer against injury from the presence of harmful weeds. This will be discussed in the following paragraphs.

In order to conform with the law governing the inspection of fertilizers, it would seem advisable to invest the taking of and analysis of seed samples in the State Board of Agriculture. This Board should be authorized to appoint the persons who would collect the samples, make the analyses and prepare the reports. Violations of the law should be certified by the Board to the proper authorities in order that they may be prosecuted.

It seems illogical to permit packages of seed weighing under a pound to escape the provisions of the law. It is very evident that the lawn grass mixtures previously referred to are especially intended to avoid the penalties for impure seed for almost all cases they are just under a pound in weight. Then there seems to be no good reason why the small packets of seed should not be required to be as pure as seed sold in bulk. If these sealed packets are also made subject to the pure seed law, some provision should be made to hold the firm putting them up responsible if it is a Michigan firm and not the retailer, provided the latter destroys or returns to the wholesaler, the illegal packets. Of course, if the offending seed firm is one outside of Michigan the retailer must be held responsible. Should this change be made, the man deputized to collect seed samples should be authorized to take whole packets where these weigh under one pound.

Germination tests should not be required in all cases as they are difficult to make for some kinds of seed and require considerable time and space. However, it seems it might be well to authorize the Board of Agriculture to have such tests made where there is a suspicion that the seed is old and of poor germinating quality. As a standard would be suggested the standards of germination adopted by the Seed Laboratory of the United States Department of Agriculture with the provision that seed falling more than a certain per cent below this standard in their germination should be declared in violation of the law.

In view of the fact that it is practically impossible to make investigation of seeds from all dealers in the state, it seems unfair to require publication of all analyses. Perhaps it would be fairer to publish only those analyses where the person concerned had been convicted by due process of law of having violated the law or only those where samples were taken and analyzed at the demand of some purchaser who suspected the seed of being impure.

The results of the analyses of seeds as shown in the tables and discussions in the earlier part of the bulletin lead the writer to make the following suggestions regarding sections 6 and 7 of the law.

Seeds should fall into three classes, those whose sale is illegal, those which may be sold when accompanied with a statement that they

contain not over a definite amount (to be considered below) of foreign matter and "pure seed" which does not contain over a very low maximum of foreign matter. Labeling as "pure," seed that comes in either of the other classes should be a violation of the law.

It should be forbidden to label or offer for sale as "pure seed" any seed containing over one half of one per cent of other kinds of seed or over one per cent of inert matter.

The second class should include seed containing not over five per cent inert matter and not over two per cent of any one kind of weed seed or five per cent in total of weed seeds or over ten per cent total of other agricultural seeds.

Chaffy grasses such as timothy, orchard grass, blue grass, etc., by repeated handling lose some of the grains out of the chaff so that an analysis might show a larger amount of chaff than allowed under these provisions, without in reality reducing the amount of seeds actually present. For this reason, such chaffy grasses, i. e. all members of the family Gramineae (or Poaceae) whose grains are ordinarily included in the chaff in the form in which they are offered for sale, should be allowed to contain ten per cent of inert matter or perhaps fifteen per cent, although the latter would be rather high.

Seeds of this class should be provided with a tag or label stating that "This seed contains inert matter not exceeding ——— per cent and weed seed not exceeding ——— per cent." The maximum per cent written on the tag or label should not exceed the limits given above. In place of the word "weed" the name of the contaminating seeds may be inserted, with or without the individual amounts but with the total amount given in any case. If other agricultural seeds be present in more than ten per cent, the lot should be considered as a mixture and labeled as such with the proportions of the ingredients. A variation of over five per cent in either direction from the formula given should be considered a violation of the law.

The third class of seeds whose sale should be forbidden in all cases should include: (1) all seed in which occur any seeds of dodder (*Cuscuta* of any species), Canada thistle (*Cirsium arvense or Carduus arvensis*), Quack grass (*Agropyron repens*) and possibly Orange Hawkweed (*Hieracium aurantiacum*). To determine this, any one of these seeds should be considered as present if it is found in two different standard sized lots out of the same sample, these standard sized lots being of the sizes used by the Seed Laboratory of the United States Department of Agriculture in its analyses. As examples, it may be stated that five grams is the standard size for analyses for red clover and alfalfa, one gram for the smaller grass seeds, etc. (2) All seed containing over five per cent of inert matter. (3) All seed containing over two per cent of any one kind of weed not enumerated above (1) or over five per cent in total (and in that case, the seed must be labeled as provided for class two) or over ten per cent of other agricultural seed except as provided for as mixtures of seed.

In the above provisions, the percentage should always be calculated by weight not by number as the latter varies with every lot of seed.

Inert matter should be defined as all non-living matter not a part of the living seeds, such as loose chaff, straw, pieces of stems, leaves, flowers, sand, dirt, pieces of stone, etc., as well as all broken or insect-

eaten seeds and shrunken empty seed coats. Mere discoloration or slight shrinking of seeds should not put them among inert matter.

The purpose of the foregoing classification is to make it desirable on the part of dealers to aim to attain a high standard of quality so as to be able to grade the seed as "pure." On the other hand, it will, enable dealers who do not have the appliances for cleaning the seed properly to offer it for sale (provided it is not too foul) if a statement accompanies it that will show the prospective purchaser that he is not getting pure seed.

The State Board of Agriculture should be authorized to charge a moderate fee for all analyses of seeds sent in voluntarily, this to be required of all or only of seed dealers or not at all at the discretion of the Board. It may often occur that it is desirable to encourage farmers or seed dealers to send in seeds for analysis and in such cases, the fees would not be charged; on the other hand, certain seed firms have made use of the College in the past to analyze their seed samples instead of having a seed analyst of their own and for such cases, it seems desirable to be authorized to charge a small fee for analysis and another for any germination test requested.

The expense of the seed analyses, taking samples, etc., should be borne either directly by the State as at present or by the imposition of a small annual license fee upon all seed dealers (perhaps exempting firms or persons who offer only small packets of flower and garden seeds and not seed in bulk).

ALFALFA GROWING IN MICHIGAN.

Bulletin No. 271.

The growing of alfalfa in Michigan was being discussed as early as 1888 and a number of seedings were doubtless made at that time. During the middle '90s more interest seems to have been taken in this crop and experimental seedings were more generally made. From that time to within the last few years alfalfa has been slowly but steadily gaining ground throughout the state. While most of the earlier seedings proved unsuccessful, there are several fields in the state which have been seeded to alfalfa continuously for a period of twelve or fifteen years or more and which are still fairly good stands and are producing satisfactory crops each year.

Many factors were responsible for these early failures; the alfalfa was frequently seeded on low, poorly drained land; the seed bed was quickly and poorly prepared in many cases; no means were taken to secure inoculation by the alfalfa bacteria and in practically none of the trials was lime applied to the soil. In some instances the alfalfa made a good stand and produced profitable crops for one or two seasons and then was winter killed.

Because the seeding of alfalfa was so generally a failure, in its early history in Michigan, it was not highly esteemed among the farmers of the state and for years it was questioned even by the Experiment Station whether it would ever prove to be a profitable crop and suited to general planting. During the past five or six years, however, attempts to grow alfalfa have been more generally successful. The number of trials and the acreage seeded have increased until now alfalfa is becoming quite a common crop throughout the better agricultural sections of the state and many farmers, believing that it has passed the experimental stage, are seeding large fields.

While the College could give little encouragement in the growing of alfalfa when the earlier attempts were made to grow it here, it has done much during the past several years to encourage its introduction as a general hay and forage crop throughout the state. The College has advised thousands of farmers in seeding alfalfa both through its correspondence and through its institute work, and during the past three seasons it has undertaken a practical method of assisting the farmers by sending an expert from the College to advise the farmer on his own farm, in case an alfalfa club of ten or more members is organized.

The College is also doing extensive work in the breeding of new types of alfalfa which are productive of hay and seed and otherwise well suited to Michigan conditions. This work has progressed far enough so that it has been possible to distribute a small quantity of seed of several improved strains which were developed originally from individual plants.

The Experiment Station has issued several valuable publications on the growing of alfalfa but a need has been felt during the past few years of a more recent publication on this subject. In order to learn with what success alfalfa is being seeded and what methods are giving the best results and to secure other data for such a bulletin, report blanks as per copy below were sent to a large number of farmers, who in recent years have corresponded with the College in regard to the growing of alfalfa.

MICHIGAN AGRICULTURAL COLLEGE

DEPARTMENT OF FARM CROPS

ALFALFA REPORT

The farmer receiving this blank is requested to answer the following questions in regard to his experience in growing alfalfa and return the same to the above address. The information received will be of great value to the College in studying the conditions under which alfalfa is grown in Michigan and the results of the investigation will be published in bulletin form.

If exact data is not available please make as close approximation as possible.

Name of farmer making this report..................................Address..................

County................................Distance and direction from town......................

Is your alfalfa field clay, clay loam, sandy loam or sandy?...

What is the nature of the subsoil?...

Is the field level or rolling?..

Is the soil porous so that natural drainage though the soil is good? ....

At what depth do you find standing water?..

Is there any tile drainage in the field or is any needed?...

What is the condition to the field as to fertility?...

What crops have been grown on the field for 2 or 3 years previous to seeding alfalfa?..............

....

Was alfalfa ever seeded on the field before?..

Has the field been very weedy during the past few years?......................Did you plow in preparing to seed alfalfa, if so, when?..........................Did you roll the field?............

How many times did you harrow or cultivate the field?...

Was the field quite solid and firm at the time of seeding or was it loose and soft like a cornfield usually is at time of planting?..

Was any manure applied? If so, state amount and kind and whether top dressed or plowed under.....

....

Was any fertilizer used? If so, state kind and amount...

....

Was any lime used? If so, state kind, amount and method of application.......................

....

Did you inoculate the soil? If so, how?...

Is the wild sweet clover common about roads and waste places? If so, how close to field?..........

How many acres were seeded in this field?...

What was the approximate date of seeding?..19........

How was the seed applied and covered?...

How many pounds were seeded per acre?..

Where did you purchase the seed and was it northern grown?.....................................

Did you inoculate the seed, if so, where did you get the nitro-culture and how many days after its receipt before it was applied to the seed?..

....

Did you sow any other crop with the alfalfa as a nurse crop, if so, what, and how much seed per acre?..

....

When was the nurse crop cut?..

Was the alfalfa in good condition at this time and did it suffer from hot dry weather during the next few days?...

....

Did the alfalfa come up and make a thick even stand?..

Was the alfalfa of a healthy color and vigorous growth during the first season or was it yellowish with small spots of darker green and more vigorous growth?..

Did you examine the roots for nodules, if so, did you find many?..
What treatment did you give the field the first season after seeding?..................................
Have there been many weeds in the field since seeding, if so, what kinds?.............................
....
Have you disced your alfalfa, if so, with what results?...
How many times do you cut your alfalfa in a season?...
What is your total yield of hay per acre?..
What is your estimated feeding value of the hay per ton?..
Have you pastured cattle or sheep on alfalfa, if so, with what results?................................
Have you pastured hogs or other stock on alfalfa, if so, with what results?.........................
Have you ever attempted to grow a crop of alfalfa seed, if so, what crop did you save?.............
What was the weather during bloom and after bloom?..
What was the total amount of seed produced and the yield of seed per acre?.......................
What is the total acreage of alfalfa on your farm at the present time?................................
Do you require additional blanks to report other fields?...
What is your estimate of alfalfa as a farm crop in your section of the state?........................
....
....
....
Discuss below any points not included in the above questions:...
....
....
....

Fig. I. A plot of alfalfa on the college farm which has produced an average yield of 5.2 tons per acre during the past 4 years.

The first of these blanks were sent out in August, 1911. About seventy per cent of the seedings first reported upon were seeded previous to 1911. In August, 1912, a second blank was sent out to all who reported in 1911, so as to get additional data from the same fields. At the same time blanks were sent to a new list of alfalfa growers. The data for this

TABLE I.—RESULTS OF SEEDING ALFALFA BY COUNTIES.

Counties.	No. of seedings reported.	Percentage of reports graded as			
		Good.	Medium.	Poor.	Failure.
Alcona	1	....	....	100	....
Allegan	38	53	23	13	11
Alpena	3	33	....	66	....
Antrim	25	36	44	20	....
Arenac	1	....	100	....	....
Barry	20	47	38	9	6
Bay	20	50	50	....	....
Benzie	8	50	25	25	....
Berrien	22	55	18	13	14
Branch	27	52	30	7	11
Calhoun	43	56	16	19	9
Cass	19	47	16	37	....
Charlevoix	5	20	40	40	....
Cheboygan	9	44	33	22	....
Chippewa	1	100	....	....	....
Clare	3	67	33	....	....
Clinton	11	45	35	20	....
Crawford	1	....	....	100	....
Dickinson	1	100	....	....	....
Eaton	18	39	44	17	....
Emmet	8	62	25	....	13
Genesee	12	58	42	....	....
Gladwin	1	100	....	....	....
Gratiot	4	75	25	....	....
Grand Traverse	10	20	50	30	....
Hillsdale	46	74	6	15	5
Houghton	2	50	....	....	50
Huron	6	50	33	16	....
Ingham	11	57	13	29	....
Iosco	8	62	....	38	....
Ionia	9	77	22	....	....
Iron	2	50	....	50	....
Isabella	11	36	37	18	9
Jackson	33	64	23	9	3
Kalamazoo	18	55	24	11	10
Kalkaska	15	7	26	34	33
Kent	20	40	30	25	5
Lapeer	10	60	30	10	....
Lake	2	50	50	....	....
Leelanau	8	....	62	25	12
Lenawee	23	61	13	9	17
Livingston	10	50	50	....	....
Luce	1	100	....	....	....
Manistee	14	7	59	29	7
Mason	6	33	34	33	....
Marquette	1	....	....	....	100
Macomb	7	57	28	14	....
Mecosta	20	25	40	20	15
Menominee	10	30	30	40	....
Midland	1	....	100	....	....
Montcalm	25	36	24	28	11
Missaukee	4	25	25	....	50
Montmorency	1	....	100	....	....
Monroe	11	54	27	9	9
Muskegon	18	39	17	22	22
Newaygo	14	28	43	21	7
Oakland	41	27	49	15	9
Oceana	11	35	28	19	18
Osceola	19	63	21	10	5
Otsego	7	57	28	14	....

TABLE I.—Concluded.

Counties.	No. of seedings reported.	Percentage of reports graded as			
		Good.	Medium.	Poor.	Failure.
Ogemaw	4	50	25	25	....
Ottawa	20	45	20	30	5
Presque Isle	8	62	13	25	....
Saginaw	5	20	20	40	20
St. Clair	34	44	27	17	12
St. Joseph	10	60	20	20	....
Sanilac	16	75	13	12	....
Schoolcraft	1	....	....	100	....
Tuscola	7	57	43	....	....
Van Buren	24	46	25	25	4
Washtenaw	18	23	22	50	5
Wayne	20	35	35	25	5
Wexford	40	30	47	23	....

bulletin is based mainly upon these reports representing 701 different seedings and a total acreage of approximately 4065 acres. Much supplementary data has also been gathered by the College field agent, who has visited several hundred alfalfa fields each season for the past three years and made careful records of methods of seeding, condition of crop, etc. Seventy-three of the eighty-three counties of the state are represented in the reports. Table I gives the number of seedings reported upon and the results with which the seedings have been made in the different counties. The number of seedings reported must not be taken as an indication of the number of fields seeded to alfalfa in the several counties, as in most of the counties there are now a large number of seedings upon which reports have never been made to the College.

CAUSES OF FAILURE OR POOR RESULTS IN SEEDING ALFALFA.

The reports from farmers were first carefully graded as to whether the seedings produced good, medium or poor results or failure. Answers to several of the questions were studied in making these grades. In some cases it was difficult to determine the grade but it is thought that on the whole the grades represent fairly well the true conditions. So far as possible the grading of the reports of 1911 seedings (in regard to which there was most doubt) have been checked up by the 1912 reports. The reports that were graded poor or failure were then carefully studied as to the most conspicuous causes of these conditions, Table II giving the results of this study.

TABLE II.—PRINCIPAL CAUSES OF POOR RESULTS OR FAILURE IN SEEDING ALFALFA.

Poor preparation of seed bed	34.4%
Lack of inoculation	30.6%
Winter killing	12.4%
Weeds	9.7%
Light, infertile soil	5.9%
Seeding with nurse crop	4.3%
Insufficient drainage	2.7%

It will be noticed by the above table that the largest percentage of

unsuccessful seedings resulted from insufficient preparation of the seed bed. To this number should be added the percentage of failures due to weeds as the weeds are the result of poor preparation of the seed bed. Failure to secure sufficient inoculation also accounts for a large percentage of the unsuccessful seedings. Twelve and four-tenths per cent of the failures were caused by winter killing. About 6.2 per cent of the total number of seedings were partially or wholly winter killed. The figures in the table indicate little as to whether the use of a nurse crop is advisable, but they show that in 4 3-10 per cent of the unsuccessful seedings, the use of the nurse crop was the principal cause of failure. The department's study of alfalfa fields over the state indicates that acid conditions of many Michigan soils account for many of the poor results in seeding alfalfa, but in most cases in the study of these reports it was either not the most conspicuous factor of failure or the lime was put on or left off the entire field so that the reports furnished little data on this point.

INFLUENCE OF TYPE OF SOIL AND CHOICE OF LOCATION FOR SEEDING ALFALFA.

In Table III the reports are classified according to the type of soil and subsoil and the groups are arranged in order of the percentages of successful seedings. In the first column of figures the number of seedings on the different types of soil are shown and in the last four columns are shown the results of seeding on the different types of soil.

TABLE III.—INFLUENCE OF SOIL IN SEEDING ALFALFA.

Soil.	Subsoil.	Number of seedings reported.	Percentage of seedings graded as			
			Good.	Medium.	Poor.	Failure.
Gravel	Clay	12	72.7	18.3	9.0	0
Gravel	Gravel	13	53.8	38.5	7.7	0
Clay loam	Gravel	14	50.0	42.9	7.1	0
Clay loam	Clay	172	52.7	29.0	16.5	1.8
Clay	Clay	28	51.8	29.7	14.8	3.7
Sandy loam	Clay	99	44.9	31.6	18.4	5.1
Sandy loam	Gravel	46	35.6	42.2	22.2	0
Sand	Clay	22	23.8	52.5	19.0	4.7
Sandy loam	Sand	51	28.3	34.0	26.4	11.3
Sand	Sand	69	14.7	33.8	39.8	11.7
Sand	Gravel	13	7.7	15.4	61.5	15.4
Total		542				

A classification of soils made by so many different parties must necessarily be somewhat inexact and doubtless some of these soils classified, for instance, as sand or sandy loam in one section of the state may be quite different from soils given the same classification in another section of the state. In one section the heavier soils and in another section the lighter soils may give best results.

Still some valuable information may be gained from these data. All the soils containing gravel either in the surface soil or subsoil, with the exception of the sand with a gravel, probably in most cases a sandy

gravel subsoil, have given very good results. It is believed that these soils are well suited to the growing of alfalfa largely because of the good drainage to a sufficient depth to allow the deep root system of the alfalfa to develop. The sand soil with either a sand or gravel subsoil have given the poorest results, probably because of their relatively low state of fertility and their poor water holding capacity. It will be noticed that alfalfa is being grown successfully on all the types of soils and that on most of the types a fair percentage of the seedings have been successful.

In choosing a field of the farm for the growing of alfalfa, it is important to avoid poorly drained soil or that in which the water table lies within three or four feet of the surface. Likewise soils underlaid with rock or other impervious strata within a short distance of the surface should be avoided. However, most of the so-called hard pans of Michigan are not too hard for the alfalfa roots to penetrate when there is plenty of moisture in the soil. Muck soils and heavy inpervious clays are poorly suited to the growing of alfalfa.

Other things being equal the fertile soils are preferable to the infertile ones. In sections of the state where the lighter soil types prevail, the seeding of alfalfa is quite commonly a failure because of the unproductiveness of the soil. While the alfalfa after it is well established in the soil is a very hardy plant, it is very tender and very slow to develop in its early growth. Alfalfa is a very valuable crop on these lighter types of soil if a good stand can be secured and the alfalfa can be made to survive the first one or two seasons, but it is not advisable to sow alfalfa on many of these soils until some means are taken to improve them. Not only is the plant food lacking but there is very little organic matter and only a very limited water holding capacity. The best way to build up a soil of this type is to grow rye, vetch or other crops for plowing under.

In the better agricultural sections of the state it is frequently advisable to seed the alfalfa on the higher, lighter lands of the farm, because this land is well drained, because the alfalfa will do very well on land of this type and because this plan will leave the best land of the farm to be devoted to other crops.

So far as previous cropping is concerned, alfalfa may follow any crop of the farm providing a sufficient length of time is taken to prepare a suitable seed bed. It is not, however, advisable to break up sod, especially a June grass sod and seed alfalfa, since the sod is not apt to be sufficiently decomposed or the grass completely eradicated before seeding alfalfa. A cultivated crop, such as potatoes, corn, or beans in which thorough cultivation has been practiced is well suited to precede alfalfa. Alfalfa may also follow any of the small grain crops but it is not usually advisable to attempt to seed the alfalfa the same season, as the grain crop generally leaves the field in a rather dry condition so that it would be difficult to prepare a good seed bed sufficiently early.

PREPARATION OF THE SEED BED FOR ALFALFA.

In Table IV is given a summary of the reports based on the firmness of the seed bed, this condition being judged by the answers to this question and also those on the methods and length of time used in preparing

the seed bed. In Table V is given another summary, based on the length of time in which the seed bed was in course of preparation. In these tables the importance of having a firm seed bed is clearly indicated and in the latter is shown the difficulty of securing this condition in the seed bed prepared in a short time. These data are borne out by observations of many alfalfa fields in which the stand has been better and the growth more satisfactory where the horses had turned or where the field for any reason had been more thoroughly firmed.

Another very important consideration in preparing to seed alfalfa is the eradication of the weeds. The alfalfa seed is rather slow to germinate and the young plants make a slow growth for sometime. As demonstrated by the Kansas Station about ½ of the plants in a normal stand of alfalfa die out in the first one or two years. Many of the weeds, especially such grasses as June Grass and quack grass are vigorous crowders and if they once get a foothold will, after a time, take possession of the field. Unlike the seeding of clover it is generally desirable to leave a good stand of alfalfa for several years. For these several reasons it is important to have the weeds more thoroughly eradicated than for other crops of the farm. It is not sufficient simply to have a seed bed free from weeds at the time of seeding but the soil should be cultivated long enough after plowing to germinate and destroy most of the weed seeds in the surface soil so that the alfalfa shall have but little competition from the weeds until it is sufficiently well established in the soil to make a rapid growth.

TABLE IV.—INFLUENCE OF SEED BED IN SEEDING ALFALFA.

Condition at time of seeding.	No. of seedings reported.	Percentage of reports graded as			
		Good.	Medium.	Poor.	Failure.
Firm	300	50.8	28.0	18.7	.2
Medium	120	44.0	35.0	16.0	.4
Loose	139	24.1	14.0	58.6	.3
Total	559	....	....	....	....

TABLE V.—INFLUENCE OF SEED BED IN SEEDING ALFALFA.

Length of time in preparing seed bed.	No. of seedings reported.	Percentage of seedings graded as			
		Good.	Medium.	Poor.	Failure.
Eight weeks or longer	224	50.0	23.3	21.3	5.4
4 to 7 weeks	158	32.9	32.9	27.3	6.9
3 weeks or less	161	31.7	40.4	24.8	3.1
Total	513	....	....	....	....

On the heavier types of soil, and in fields that are inclined to be foul, it is advised that the seed bed be prepared in the following manner: Plow late in the fall or as early as convenient in the spirng, roll and harrow, or harrow twice, immediately following the plow. Harrow once each week until late spring or early summer, when a good seed bed will have been prepared. The tramping of the horses and the rains falling during the spring months will have thoroughly firmed the soil underneath, the surface soil will be in a good tilth, the weeds in the surface soil will have been rather thoroughly eradicated and enough moisture will have been conserved to germinate the seed soon after sowing even though the seeding is done in a dry time.

In the earlier spring seedings the same method should be carried out so far as possible. In this case it is more important to plow in the fall

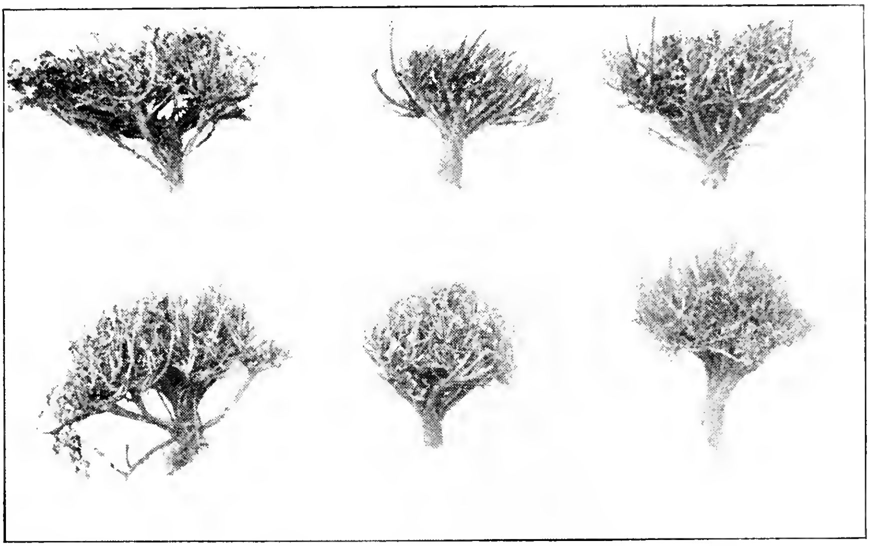

Fig. II. Alfalfa crowns. Notice the tap root, the large number of stalks and that some of the branches appear below the surface of the soil.

but the soil should receive no other treatment until spring. A very good seed bed may be prepared without plowing, in fields which have received very thorough cultivation in a cultivated crop the preceeding season, or the alfalfa may follow to advantage a crop of early potatoes with little extra preparation of the seed bed. The condition especially to be avoided in seeding alfalfa is the loose, open seed bed, such as is prepared in plowing only a short time before seeding.

USE OF MANURE IN SEEDING ALFALFA.

On the seed bed which is in course of preparation for some time the use of manure is advisable. It may be applied before plowing and turned under or it may be applied soon after plowing and incorporated in the surface soil by harrowing. In either case the manure would add

plant food to the soil, which is quite important under certain soil conditions and in the latter method would act also as a mulch and as a protection to the young alfalfa. On the seed bed which is prepared in a short time it is not advisable to use manure as a top dressing, because of its introduction of weed seeds and not, at least as a heavy coat, for turning under as it would tend to hold up the furrow slice and allow it to dry out. Another method of applying manure that is giving very satisfactory results is to spread with a manure spreader in the fall at the end of the season's growth. This is especially advisable in rather late seedings or when seeding on exposed fields which would be apt to winter kill badly.

USE OF FERTILIZERS IN SEEDING ALFALFA.

The large percentage of successful seedings reported and the small percentage of these in which commercial fertilizers have been used, indicate that its use is not as essential as the preparation of a suitable seed bed, inoculation with the alfalfa bacteria and several other factors. (Commercial fertilizers were used on 18.8 per cent of the total number of seedings reported upon.) There are doubtless conditions under which the judicious use of commercial fertilizers will enhance the chances of success in the seeding of alfalfa. Under other conditions fertilizers may be used with little if any apparant effect and certainly the use of fertilizers as a panacea for all the troubles of alfalfa growing is sure to result in a good many disappointments. This is a matter largely dependable upon local conditions. No attempt is here made to give any recommendations in regard to the use of fertilizers which will apply generally to farm conditions. It is suggested rather that simple experiments be conducted to learn what fertilizers, if any, may be used with profit under local conditions.

As a means of stimulating a more vigorous growth in new seedings of alfalfa, the use of 200 lbs. per acre of a complete fertilizer, such as a 2—8—6, for sandy or sandy loam soils, and a 2— 10— 4 for clay or clay loam soils is suggested. Other fertilizers of different analyses, both complete and incomplete, might also be included in the experiment.

Alfalfa has in numerous instances throughout the state produced satisfactory crops of three to five tons per acre on light loamy or gravelly soils of apparently low fertility and continued to do so for periods of five to fifteen years or more, so that there would seem to be little need of applying fertilizers after the alfalfa is well established in the soil. Since alfalfa is a leguminous crop, the supply of nitrogen would doubtless be maintained by the fixation of nitrogen from the atmosphere. Certainly it would not be a profitable investment to buy commercial nitrogen for applying to alfalfa fields after the first year. Some of the lighter Michigan soils, however, contain a rather low supply of phosphoric acid and this would tend to become exhausted by the continual removal of the crops. Our clay soils should contain a sufficient supply of potash for the production of satifactory crops for an indefinite period. The sandy soils which contain very little clay should, however, be benefitted by the application of potash. These requirements may be supplied in part at least by the application of a coat of well rotted manure an-

nually. The application of 200 to 250 pounds of acid phosphate or 100 or 150 pounds of steamed bone meal might be applied as an experiment on clay soils, as might also the same fertilizer with the addition of 75 to 100 pounds of muriate of potash on the sandy soils.

USE OF LIME IN SEEDING ALFALFA.

Only about twenty-five per cent of the farmers who filled out the report blanks used lime at all and over one-third of these applied it at less than 1000 pounds per acre. It is, therefore, evident, considering the large percentage of successful seedings, that the use of lime is not an essential factor in the seeding of alfalfa on many of the farms in Michigan. It is just as evident, however, as shown by many observations about the state and by numerous reports from farmers that, under certain soil conditions, the use of lime is quite essential to the growing of this crop.

Table VI shows the summarized results of the use of lime as compared with no lime.

TABLE VI.—INFLUENCE OF LIME IN GROWING ALFALFA.

Treatment.	No. of seedings reported.	Percentage of seedings graded as			
		Good.	Medium.	Poor.	Failure.
Limed	138	50.1	25.7	31.2	.1
Not limed	412	33.9	33.1	25.1	7.9

It is sometimes difficult to tell by preliminary study whether an application of lime is needed before seeding alfalfa. If the surface soil contains small shells or small pieces of limestone, it probably is not in an acid condition. Pebbles that are thought to be of limestone origin (and also the soil itself) may be tested by pouring on a small amount of hydrochloric or other acid. If an effervesence or bubbling takes place it indicates an alkaline condition, and an application of lime is not necessary. When much difficulty is experienced in producing satisfactory crops of red clover, it may be taken as an indication of some unfavorable condition, possibly an acid condition of the soil. The use of litmus paper is often of value in determining whether lime is necessary. In order to make this test, the blue litmus paper, should be purchased at a drug store, and the strips placed in the moist soil in various parts of the field and left there for five or ten minutes. If the paper turns to a reddish color it is said to indicate an acid condition of the soil. This, however, is rather a crude test and may be misleading either from the fact that the blue dye may be absorbed by the soil, leaving the paper red or because much of the litmus paper on the market is not sufficiently sensitive to determine slightly acid conditions of the soil. By far the most satisfactory method of determining this point is to apply lime on a portion of the field where alfalfa is being seeded. It is recommended that this be done in all cases of seeding alfalfa for the first time on the farm. The results of such a test will on the whole direct the farmer wisely in future seedings of alfalfa.

There are several forms of commercial lime which may be used to correct the acidity of the soil, the most important of these being as follows: ground limestone, or the finely pulverized raw rock; burned lime, or quick lime, which is produced from the raw rock by burning, the hydrated lime which is the product of the application of water to the burned lime; and the air slacked lime, which is the burned lime which has been exposed to the atmosphere and has partially reverted to the hydrate and carbonate forms. The refuse lime from sugar factories is much the same as the air slacked lime but contains in addition a small percentage of nitrogen, phosphoric acid and potash. Marl is another available source in many sections of the state. The choice of the form of lime depends upon the relative price, the chemical composition, fineness of pulverization, cost of freight and hauling, etc. One hundred pounds of carbonate of lime, such as is found in the ground limestone and marl is equivalent to seventy-four pounds of hydrated lime and fifty-six pounds of burned lime. When marl or sugar factory lime may be applied without too great labor expense, these forms may be the cheapest that can be secured. In most sections of the state the ground limestone may be had at lower cost than other forms of commercial lime.

The amount of lime required depends upon the degree of the acidity of the soil, but as this is difficult to determine, it is recommended that the lime be applied at the rate of at least two tons per acre of the ground limestone or its equivalent in the other forms. There is no danger of applying too much of the carbonate forms up to several tons per acre and if a medium heavy application is made the value of the application is more certain to be determined and any soil acidity which may exist in the soil will remain corrected for a longer time than if a light application be made.

One of the most satisfactory methods of distributing the various pulverized forms of lime is to use one of the modern lime distributors, of which there are several on the market. Another satisfactory method is to use the manure spreader, filling the box about ½ full with manure and filling the remainder of the box with the lime. Fertilizer attachments to grain drills are sometimes used but this method is not so satisfactory when it is desired to apply a fairly large amount per acre. If the burned lime is the most convenient form to secure, this should be placed in small piles in the field until it absorbs enough moisture from the soil and air to become finely pulverized and then it may be spread with a shovel.

INOCULATION OF ALFALFA.

There is no question as to the importance of the bacteria which are associated with the various leguminous plants. In the absence of the bacteria the nodules do not develop on the roots and the plant is not able to take its nitrogen from the atmosphere. The legumionus crop thus becomes a soil robber the same as the non-leguminous crops and the growth is apt to be stunted and the crop unprofitable.

The red clover is so commonly grown in the Northern states that the bacteria which are associated with this species are thoroughly disseminated and artificial inoculation is generally of little if any value.

Alfalfa, however, is a new crop, with few exceptions never having been grown in the same field before, hence the need of introducing the bacteria artificially. The lack of inoculation has been found to be responsible for a very large percentage of the failures in the earlier seedings of alfalfa in Michigan. Even at the present time when alfalfa is being seeded so commonly and the chances are so much more favorable for inoculation by natural means, the artificial inoculation is practically essential to the securing of a successful seeding.

There are several ways in which the bacteria may be introduced into a new field e. g. by the application of soil from a field which has grown one or more tubercle bearing crops of alfalfa; by the use of pure cultures, which are generally applied to the seed; by the bacteria being carried by the seed from the old field to the new; by the growth of closely related species with which the same bacteria are associated; by the application of alfalfa manure; and by various natural means, such as moving water, wind, etc. The chief objections to the first method are the possible introduction of noxious weed seeds and in some cases the cost of transportation and application. This method has, however, given very satisfactory results, the farmers' reports as summarized in Table VII indicating that it is somewhat more reliable than to use the pure cultures. In using this method care should be exercised to get soil in which tubercle bearing plants are growing and to avoid exposing the soil to the sunlight. It is preferable to apply it on a cloudy day or at dusk and cover at once. The more of the inoculated soil that is applied the more certain of having sufficient bacteria so that every plant will develop the nodules in its early growth, but in case the soil is secured at considerable expense 400 or 500 lbs. per acre will answer very well. The use of pure culture is by far the most common method of inoculation now being used. It is inexpensive, easy of application and gives very satisfactory results.

TABLE VII.—INOCULATION FOR ALFALFA. SOIL VS. NITRO-CULTURE.

Method of inoculation.	No. of seedings reported.	Percentage of seedings reported as			
		Good.	Medium.	Poor.	Failure.
By soil from old alfalfa field or sweet clover patch	91	50.5	37.4	11.0	1.1
By nitro-culture	363	36.4	30.9	27.8	4.9

There are always some bacteria carried by the seed from the field where the seed was produced. This accounts for the small spots of alfalfa of rank, healthy growth frequently seen in the yellowish stunted growth of the uninoculated field. If the alfalfa survives for a year or two until the bacteria in these spots are disseminated by natural means a satisfactory stand may result, but this method should never be depended upon when alfalfa is being seeded on the field for the first time and it is desired to secure a full stand of alfalfa. A most excellent practice, however, is to seed a small amount of alfalfa with the regular seeding of clover each year, as the bacteria introduced in this way will spread naturally and produce a thorough inoculation by the time it is desired

Fig. III. Showing the root and tubercle formation on young alfalfa plants. Notice that some of the tubercles are about the size of a pin head, while others are joined together in large clusters.

to seed alfalfa as a regular crop in the field a few years hence. In following this practice the seed should be treated with the nitro-culture the same as though a full stand of alfalfa were desired.

The last three methods of inoculation are not frequently employed by the farmer but help to explain why some fields in which none of the common methods of inoculation have been used, produce an abundance of tubercles from the first. As the expense is so little and the risk of partial or complete loss of crop is so great in case the bacteria are not present, artificial inoculation should by all means be used whenever alfalfa is being seeded for the first time in the field. Soils that have grown satisfactory tubercle bearing crops of alfalfa harbor the bacteria for an indefinite time so that if alfalfa is seeded again in the field even after several years, the nodules will develop on the roots in abundance.

DATE OF SEEDING.

In studying the date of seeding alfalfa the reports were first classified according to the nature of the soil with the thought that different dates of seeding might be found to be best under the different soil conditions. The data from the seedings made on light infertile soils are included in Table VIII while those from the medium and heavy soils are included in Table IX.

TABLE VIII.—DATE OF SEEDING ALFALFA.—LIGHT SOIL.

Dates of seeding.	Number of seedings reported.	Percentage of seedings graded as			
		Good.	Medium.	Poor.	Failure.
April 15 or before	1	0	100.0	0	0
April 16 to 30	7	14.2	42.9	42.9	0
May 1 to 15	14	14.3	28.6	50.0	7.1
May 16 to 31	22	27.3	13.6	50.0	9.1
June 1 to 15	38	18.4	55.3	18.4	8.0
June 16 to 30	17	23.5	17.7	41.1	17.7
July 1 to 15	4	0	25.0	50.0	25.0
July 16 to 31	5	20.0	0	60.0	20.0
August 1 to 15	7	28.6	14.2	42.9	14.2
August 16 to 31	6	17.0	17.0	50.0	17.0
September 1 or later	6	17.0	33.0	17.0	33.0
Total	127	....	....	....	....

TABLE IX.—DATE OF SEEDING ALFALFA.—MEDIUM AND HEAVY SOIL.

Dates of seeding.	Number of seedings reported.	Percentage of seedings graded as			
		Good.	Medium.	Poor.	Failure.
April 15 or before	24	41.6	29.1	29.1	0
April 16 to 30	34	35.3	47.1	14.6	2.9
May 1 to 15	50	46.0	34.0	18.0	2.0
May 16 to 31	51	41.2	39.2	17.6	2.0
June 1 to 15	71	50.7	26.8	18.3	4.2
June 16 to 30	54	59.2	25.9	12.9	1.9
July 1 to 15	23	26.1	39.1	35.0	0
July 16 to 31	25	68.0	16.0	12.0	4.0
August 1 to 15	32	46.9	31.2	18.8	3.0
August 16 to 31	19	31.6	15.8	41.6	1.0
September 1 or later	14	11.6	17.5	47.1	5.8
Total	397	....	....	....	....

The following conclusions may be drawn from these data: The date of seeding varies from very early spring until about the middle of September, the months in which alfalfa is most commonly seeded being May and June, with the latter half of June as the most popular half month. Aside from the fact that the late August and September seedings have been less satisfactory than the earlier seedings, the date of seeding is not of much importance as compared with the preparation of the seed bed and several other factors. On the medium and heavy soil types especially, the early summer seeding may be safely recommended, the chief advantage in seeding at this time being that the seed bed may be more thoroughly prepared and the weeds more thoroughly eradicated than in the earlier seedings, and the alfalfa will make a larger growth and be in a better condition to survive the winter than the late summer or fall seedings.

Fig. IV. A productive field of alfalfa near Holton, Muskegon County.

While the data in Table VII does not indicate strongly any particular date of seeding as best, it is probably true that on light soils where a summer drought is apt to be very serious, the early or middle spring is as favorable a time as any for seeding, providing a fairly favorable seed bed can be prepared.

USE OF NURSE CROP VS. SEEDING ALONE.

A summary of the data on the use of nurse crops in seeding alfalfa is presented in Table X. Fifty-two per cent of the early (spring) seedings, over ninety of the early summer seedings, over eighty-five per cent of the late summer and fall seedings, and seventy-five per cent of all the seedings were made without a nurse crop. A consideration of these facts and the large percentage of the seedings that were successful would indicate that the use of a nurse crop is not an essential

factor in the seeding of alfalfa in Michigan. In the seedings made before June 1st, slightly better results have been secured with a nurse crop than without, but in both the early and late summer seedings, much better results have been secured without than with a nurse crop. Oats, barley, wheat, rye and buckwheat were reported as having been used as nurse crops, but no conclusive data can be elaborated in regard to a choice between these.

TABLE X.—INFLUENCE OF NURSE CROP IN SEEDING ALFALFA.

Date of seeding.	Nurse crop or without nurse crop.	Number seedings reported.	Percentage of seedings graded as			
			Good.	Medium.	Poor.	Failure.
Before June 1st.	Nurse crop.........	103	41.7	37.9	18.4	1.9
	Without nurse crop..	113	41.6	23.1	27.4	7.0
June 1st to July 31	Nurse crop.........	23	39.1	26.0	26.0	9.0
	Without nurse crop..	226	43.4	31.4	17.2	4.0
September 1st and later..........	Nurse crop.........	13	15.4	15.4	53.8	15.4
	Without nurse crop..	78	40.0	26.9	24.3	9.0
Totals.....	Nurse crop.........	139	39.0	34.0	23.0	4.3
	Without nurse crop..	417	44.3	28.5	21.3	5.8

Under favorable conditions of seeding the use of a nurse crop would not seem to be advisable. The young alfalfa needs no protection from the sun and is more abundantly supplied with moisture and plant food when seeded alone than when seeded with a more vigorous growing plant to compete against it. On very light soils that are apt to be moved by the wind and on steep hillsides that are subject to washing, a nurse crop should of course be used. The nurse crop may also be advisable on fields that are in course of preparation for only a short time and the weeds not thoroughly eradicated. Under these conditions the nurse crop may assist in holding the weeds in check, and may be more easily eradicated and less objectionable generally than the common weeds. Very late seedings that are apt not to be in hardy condition at beginning of winter, may be somewhat protected by the seeding of a nurse crop although it is considered better to seed alone and apply with manure spreader, after a few weeks, a medium coat of well rotted manure to protect the young plants through the winter.

Two of the best crops for use as nurse crops in spring seedings are the fall wheat and rye as the growth is not as vigorous or the alfalfa as thoroughly shaded as with the use of spring grains. Beardless barley is more satisfactory than oats.

The nurse crop should be cut for hay rather than harvested for grain, as in the latter case the alfalfa is apt to remain spindling and tender until the nurse crop is removed, when it is exposed to the sun during the hottest part of the summer and is apt to die out badly.

DRILLING VS. BROADCASTING OF ALFALFA.

Approximately twenty-two per cent of the seedings were made with a drill and the remainder were sown by hand or with a broadcast seeder. In many of the seedings made with the drill, the drill was followed by a harrow or the seed was distributed by the seeder attachment in front of the drill so that they were essentially broadcast seedings. The data on the exact method of seeding is insufficient to justify its presentation in tabular form and the drawing of definite conclusions from the same. It may be said however, that the drilling (dropping the seed through the grain hose) has the advantage over the broadcast method in that practically all of the seed may be placed at the proper depth in the soil and that a somewhat lighter seeding will give equally good results. In a few cases alfalfa has been drilled deeply on heavy soil, followed by heavy rains which has prevented the alfalfa from coming up. On medium or heavy soils the seed should be put in to a depth of about 1 inch and on the light sandy soils, to a depth of 1½ to 2 inches.

RATE OF SEEDING ALFALFA.

Table XI shows the number of seedings which have been made at different rates and the percentage of good, medium and poor seedings and failures in each class. It may be noted from the table that approximately one-half of the seedings were made at the rate of sixteen to twenty pounds per acre, one fourth at thirteen to fifteen pounds per acre and one tenth at ten to twelve pounds per acre, there being very few seedings at less than ten or more than twenty pounds per acre. The average rate per acre was 17.8 pounds.

TABLE XI.—RATE OF SEEDING ALFALFA.

Rates of seeding.	Number of seedings reported.	Percentage of seedings graded as			
		Good.	Medium.	Poor.	Failure.
Less than 10 pounds	16	43.8	37.5	18.8	00
10 to 12 pounds	51	35.2	22.2	37.0	5.5
13 to 15 pounds	136	33.1	39.6	22.1	5.1
16 to 20 pounds	251	43.4	25.9	25.9	4.8
21 to 25 pounds	26	50.0	27.0	19.0	3.8
Over 25 pounds	29	41.3	31.5	17.3	6.9
Total	512				

The above data does not indicate that the rate of seeding within certain limits is a very important factor in the seeding of alfalfa. A pound of alfalfa seed contains approximately 150,000 seeds so that a seeding of ten pounds per acre is equivalent to thirty four seeds per square foot. It may be readily seen that this application, or even five or six pounds per acre, is sufficient if the seed is good, if it is evenly distributed and if covered to the proper depth on a well prepared seed bed. However, on account of the difficulty of securing conditions

that are ideal in all respects, it is doubtless safe as a general recommendation at least, to advise the use of ten or twelve pounds per acre.

TYPES OF ALFALFA.

There are no commercial varieties of alfalfa which would correspond to the different varieties of corn, oats and other cereal crops, the alfalfa being a mixture of several more or less distinct types. These types vary considerably in their habit of growth, production, adaptability, etc., and offer a splendid field for selection. The Experiment Station has devoted considerable attention to the breeding of new strains of alfalfa which are better suited to Michigan conditions and this work has

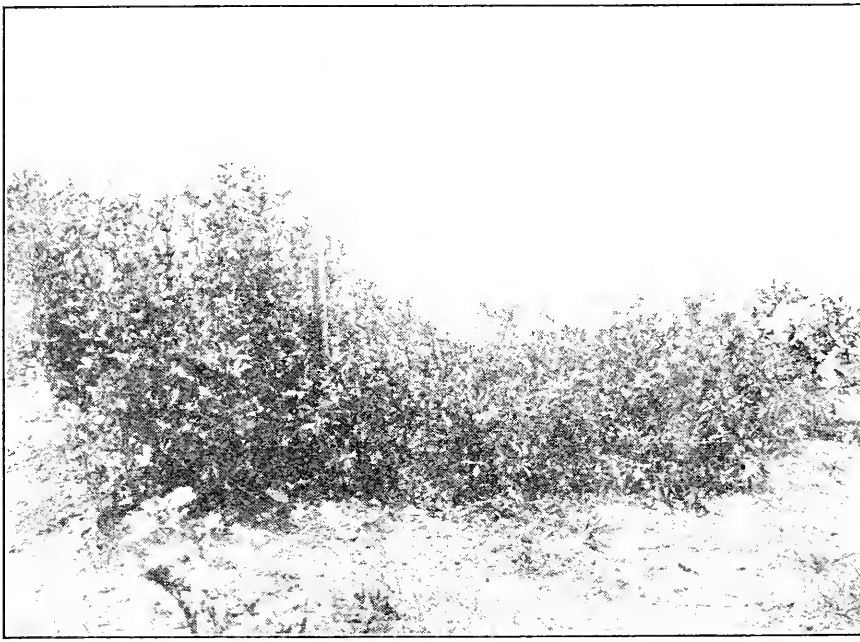

Fig. V. Showing different types of alfalfa. The plant on the left is erect, the one on the right is semi-decum bent.

progressed far enough to allow a limited distribution of seed (beginning in 1911) of some of the pure strains developed from the more promising of the individual plants in the breeding plots.

Alfalfa may conveniently be divided into three types: The Medicago Sativa or common alfalfa which is erect or nearly so, and has a blue flower and spiral shaped pod; the Medicago falcata, which is inclined to be decumbent and has a yellow flower and crescent shaped pod, and the variegated alfalfa, which is supposed to be the result of the crossing of the above two types and which is fairly erect and has a variegated blossom and is intermediate as to form of pod.

The Medicago Sativa is by far the most commonly grown in this country. The Medicago falcata, while possessed of more hardiness than the common alfalfa is not popular for general use because of its de-

cumbent growth and moderate yield. The variegated alfalfa is represented by the Grimm alfalfa, much of the commercial Sand Lucerne and some of the seed from Germany, Canada and other sources. The variegated alfalfa is generally known as a hardy, productive and an all round desirable type, but as it is not generally known among the farmers and as the common alfalfa has given satisfactory results, it is not very generally grown.

There are also many regional types of alfalfa whose characteristics have been acquired by long continued culture under conditions prevailing in certain regions. Examples of these are found in the Arabian alfalfa, the Puruvian, the German and the Turkestan. Many of these are very poorly adapted to growing in the United States; others developed under similar but somewhat more severe conditions are hardy

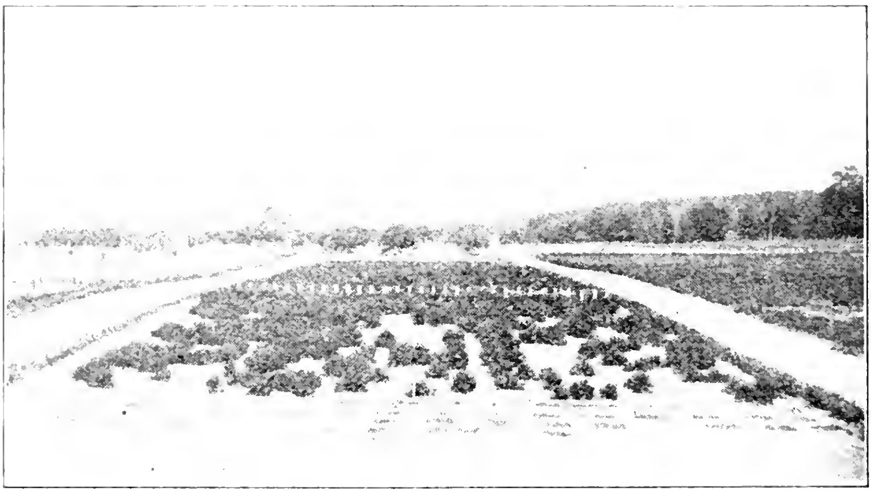

Fig. VI. A view of some of the alfalfa breeding plats at the experiment station.

and well adapted to growing here. Conditions governing the production, importation and sale of alfalfa seed, however favor the general use of American grown seed.

Approximately 42% of the alfalfa growers reporting, purchased seed which was claimed to have been northern grown and Table XII shows the results with which these seedings were made as compared with those in which the sources of seed was not specified. In many of the latter class, northern grown seed was undoubtedly used.

TABLE XII.

Source of seed	Number of seedings reported	Percentage of seedings reported as			
		Good.	Medium	Poor.	Failure
Northern grown	172	49.1	30.8	16.3	3.5
Source not specified	331	40.8	29.6	23.5	6.1

The above data would seem to indicate that the northern grown seed is better for seeding under Michigan conditions than that grown in the middle and southern states. This is as should be expected, as alfalfa seed is usually produced on fields that are several years old and if grown in the north would come from the more hardy plants which have survived several winters and not from, the less hardy plants which might have survived and produced seed in the southern states. It is recommended that farmers use the northern grown seed whenever obtainable. Seed grown in the Pacific coast states should be avoided because of the presence there of a very serious disease called alfalfa crown gall.

TREATMENT OF ALFALFA FIELDS THE FIRST SEASON.

About the only treatment it is necessary to give to an alfalfa field the first season is to cut it at the proper time and to remove any vegetation which may be so thick as to smother out the young alfalfa. The alfalfa should be cut at the proper time for cutting older stands for hay, or before this time if the leaves begin to turn yellow and fall off. It should also be mown whenever the weed growth becomes so large as to be apt to choke out the alfalfa. The young alfalfa should be cut at the usual height, as otherwise the crowns will be formed high and will be cut off the next time it is mown. Fields seeded in the early spring may need to be cut as many as three times the first season, but in other instances one cutting will be sufficient, as the alfalfa may be injured by too frequent cutting. The last cutting should be made sufficiently early in the fall to allow additional growth, to act as a protection through the winter. Usually alfalfa may be cut safely as late as the first or middle of September.

A top dressing of well rotted manure preferably applied with a manure spreader is of much value in protecting the alfalfa through the winter. It not only acts as a protection from the wind and cold but holds the snow as an additional protection. The heaving out of the young plants by alternate freezing and thawing is worst on very heavy clay soils and is more or less common on light sandy soils but is least serious on well drained loamy soils that contain considerable vegetable matter. The danger of heaving is materially lessened by the top dressing of manure or by leaving some vegetation on the ground.

DISCING OR HARROWING ALFALFA.

The cultivation of the soil after seeding, with a disc or other harrow has been practiced on eleven and one-fourth per cent of the seedings reported, but many of the stands were to young to harrow at the time of making out the reports. In Table XIII is given the data secured from this study.

TABLE XIII.—EFFECT OF DISCING OR HARROWING ALFALFA.

Classification of seedings.	Number.	Percentage.
Harrowed with good results	32	49.2
Harrowed with no apparent effect	10	15.4
Harrowed with poor results	1	1.5
No report on results or too early to tell	22	33.8

The following statements are based on data secured by the department from various sources. There seems to be no advantage in harrowing alfalfa the first two or three years after seeding, in fact there are many old fields that have never been cultivated which are producing abundantly and are in an ideal condition. The harrowing of old stands that are inclined to be thin may, however, be advantageous because of the destruction of weeds, the aeration of the soil and the creation of a soil mulch to conserve the moisture. Some writers have recommended discing on account of splitting the crowns of the alfalfa, but a careful examination of disced fields fails to reveal any appreciable percentage of split crowns. Fields in which Kentucky blue grass is well established will not be put in a clean condition by cultivation but harrowing will be of considerable benefit in postponing the grassy condition, if done when the grass is just starting in small bunches over the field. The cultivation after seeding then will not take the place of thorough preparation of the seed bed, but will, in many cases at least, result in a larger production and prolong the life of the stand. The proper time to harrow is early in the spring before the new growth starts or immediately after one of the cuttings. The spring tooth harrow is one of the best implements for harrowing alfalfa as it may be used to make a deep mulch and will disturb the alfalfa plants but little. The disc harrow is also a satisfactory implement for this purpose but should be set rather straight and weighted to make it dig properly. An old stand may be harrowed several times, so that the field will have an appearance of a newly prepared seed bed with good results, but the harrowing should all be done at once as nearly as possible and within a few days after cutting.

FUNGOUS DISEASES AND INSECT PESTS.

There are a large number of fungous diseases and insects which work on alfalfa but no attempt will be made in this bulletin to describe and give methods of treatment for all of these. The alfalfa leaf spot and the grasshoppers are mentioned, as these are subjects upon which alfalfa growers frequently request information.

The leaf spot or *Pseudopeziza medicaginis* (Lib) Sacc, is a fungous disease which is very common wherever alfalfa is grown. It may develop under all conditions of soil, season and weather and is present at least to a limited extent in practically all alfalfa fields. It shows the most marked development in moist weather, in the second or third cutting rather than the first, in the older growth more than in the new shoots and in new seedings in which the growth is stunted on account of some unfavorable conditions rather than in the older stands which are making a rapid growth. This disease is characterized by small, brown spots about the size of a pin head which appear on both sides of the leaf and along the stems but are more conspicuous on the upper surfaces. The lower leaves are the first to be attacked. Usually the leaves turn yellow and after a few days begin to fall off.

While this disease is a very common one, it is not considered very serious; it may reduce the yield of a certain cutting but does not usually destroy the stand. Little is known as to the method by which the disease is carried from one field to another and no practical

methods have been discovered which will completely eradicate it. Fields that are attacked by leaf spot should be clipped soon after the lower leaves turn yellow and begin to fall off, or when the alfalfa stops growing and the leaves are covered with brown spots, even though little or any of the yellow appearance develops. The cutting of the alfalfa will cause a new growth which will be less affected with the disease than the older growth and usually when conditions are favorable, the new crop will make about the normal growth.

While there are many insects that work on alfalfa, the depredation of the grasshopper is the most serious, especially on the light soil types of the northern part of the state. The new seedings of alfalfa frequently provide a succulent green growth when there is little other green growth in the neighborhood and it is especially subject to attacks of the grasshoppers, an entire field frequently being destroyed in a few days' time.

The following methods of combating grasshoppers are recommended by Professor R. H. Pettit in Michigan Bulletin No. 258.

"Fall plowing.—This is the most efficient where it is possible at all. Plow the egg-pods under, burying some, and breaking open others so that moisture can get in, and exposing still others to the attacks of their enemies,—birds, shrews, etc."

"Poisoned baits.—The second method is that of poisoned baits. Use either poisoned bran or the Criddle mixture. Poisoned bran can be used only in situations where stock and poultry are excluded. Neither should it be used where partridge or quail are likely to feed. It is merely bran poisoned with paris-green or arsenic, two pounds of paris-green to 100 of bran, moistened with water and a little molasses, so that the bran will just stick together when taken up with a spoon."

"Criddle mixture is horse-manure mixed with arsenic and slightly salted. It is to be distributed about the fields in small masses. We all know of the fondness of grasshoppers for anything containing salt. They will even roughen fork handles in their efforts to get at the salt deposited on them with the perspiration. This mixture is recommended in Canada and in some of the western states. The proportions are about as follows: Paris-green, one pound; salt, two pounds, fresh horse-droppings, 100 pounds. The horse-droppings are usually measured out in a three-gallon pail. Five pailfuls being taken as a right amount for one pound of the poison. The salt is dissolved in a pail of water, the poison stirred in, and the whole mixed with the droppings in a half barrel."

WEEDS IN ALFALFA FIELDS.

The worst weeds in alfalfa fields are the perennial grasses, such as Kentucky blue glass (June grass) and quack grass. In some sections of the state the late summer annual grasses such as crab grass, are serious pests. Both of these types of grasses after once being established in the field are very difficult of eradication, the only feasible method of control, especially for the first mentioned type, being a thorough preparation of the seed bed, as previously discussed in this bulletin. When the alfalfa field becomes unproductive because of the foothold gained by Kentucky blue grass or other perennial grasses, it

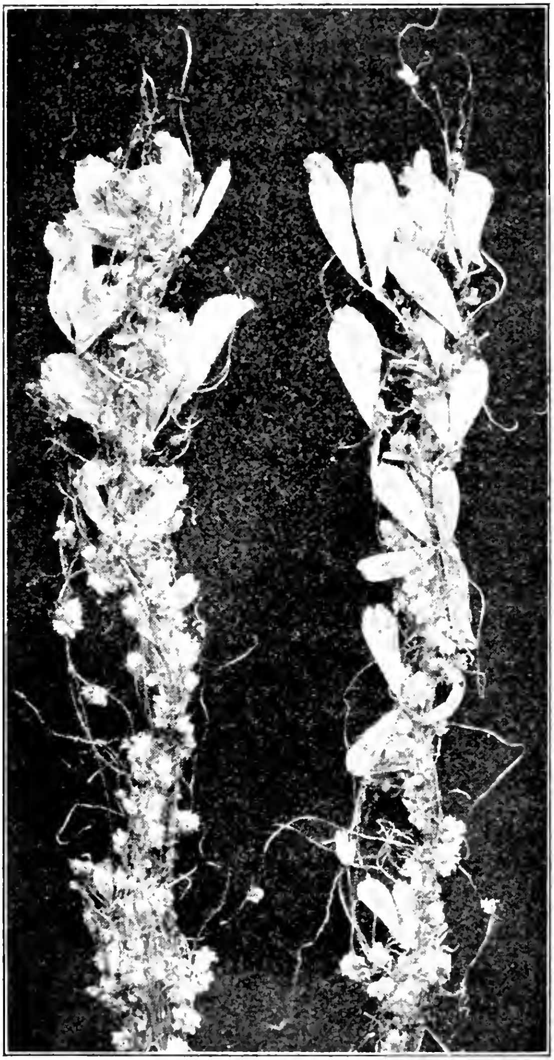

Fig. VII. Dodder growing on alfalfa.

they make a larger growth the first season, which is apt to rob the alfalfa of most of its plant food, water and sunlight and may cause it to die. Usually weeds of this type can be held in check by mowing two or three times during the season. If the alfalfa survives the first is advisable to plow the field and plant to corn or other cultivated crops, and seed alfalfa in another field.

The larger growing annual weeds are not so serious, except that season, it usually makes such rapid growth the second season, that it holds these annual weeds in check.

While the dodder is not common in alfalfa fields, it is considered one of our most objectionable weeds if once introduced on the farm. There are two species which work on the alfalfa, the clover dodder, *Cuscuta epithymum—Murr* and the field dodder, *Cuscuta arvensis—Beyrich*. Both of these species are parasitic plants, the stalks twining about the alfalfa and robbing it of its nourishment by means of little rootlets or suckers which pierce the alfalfa stalks. The plant has no leaves (only small scales). It is usually noticeable because of its whitish flower clusters.

Dodder is usually introduced in alfalfa seed and may be avoided if sufficient attention is given to the purchase of the seed. If the field is not large and there are only a few small spots of dodder, these may be destroyed by hoeing, but should be watched carefully throughout the season to see that more plants do not appear. If the dodder is found to be well scattered over the field, it is best to turn the entire crop under to prevent the formation of any seed. If any seed should be formed, it would not be advisable to attempt the growing of alfalfa in the field for a period of from four to five years.

MAKING ALFALFA HAY.

Alfalfa may be injured by too frequent cutting or if left too long without cutting will not produce the maximum yield or the best quality of hay. The proper time for cutting as determined by experiments in several states and by general experience is when it begins to bloom and the new shoots appear at the crown. Alfalfa growers are frequently inclined to delay cutting on account of unfavorable weather or the rush of other work on the farm, but the above rule should be followed rather closely. If the cutting is much delayed, the new shoots are cut off and the following crop is retarded; the plants become more woody, the leaves begin to drop off and the hay is of much poorer quality than if the crop is cut at the proper time.

In the making of alfalfa hay it is very important that most of the curing be done by the air and wind rather than by the sun. The alfalfa should be left in the swath until wilted but it should be raked before dry enough for any of the leaves to fall off. The curing should then be completed in the windrow and cock. The alfalfa may be put in the cock while still quite green, providing the weather permits it being left for several days until completely cured, the best quality of hay being made in this way. It frequently will be found, however, to be more practical to have the hay fairly well cured before cocking, or even to draw from the windrow. One is certain, however, to sacrifice more or less of the feeding value when the hay is not cocked on account of the loss of the leaves.

The tables below give the analyses of the different parts of the alfalfa plant and the proportion of total feed constituents found in the several parts.

TABLE XIV.—COMPOSITION AND DISTRIBUTION OF NUTRIENTS IN THE DRY SUBSTANCE OF HAY FROM ALFALFA CUT IN EARLY BLOOM—FIRST CUTTING.

Part of plant.	Yield per acre, pounds.	Ash.	Protein.	Fiber.	Nitrogen—free extract.	Fat.
Stalks	28.38	9.01	10.74	42.17	37.14	0.94
Leaves	18.56	14.33	24.05	13.81	41.82	5.99
Flowers	1.36	10.56	26.18	15.58	46.00	1.68
Whole plant	43.31	11.10	16.30	30.53	39.23	2.92

Kansas Bulletin No. 155.

TABLE XV.—PERCENTAGES OF ASH, PROTEIN FIBER, ETC., IN EACH OF THE DIFFERENT PARTS OF THE ALFALFA PLANT, TO TOTAL AMOUNT OF THAT CONSTITUENT IN ENTIRE PLANT—FIRST CUTTING, EARLY BLOOM.

Part of plant.	Yield per cent.	Ash.	Protein.	Fiber.	Nitrogen—free extract.	Fat.
Stalks	58.75	47.69	38.73	81.17	55.68	19.03
Leaves	38.43	49.62	56.74	17.39	41.01	79.34
Flowers	2.82	2.69	4.53	1.44	3.31	1.63

Kansas Bulletin No. 155.

It may be noticed from the above tables that about one-half of the ash, about one-half of the protein and nearly 80 per cent of the fat, the most valuable constituents for feeding, are found in the leaves. The curing of the hay in the cock largely avoids the bleaching by the sun and the exposure to rains and dew. Prof. J. T. Willard, in Kansas Bulletin, No. 155, estimates from data from the Colorado Experiment Station that alfalfa exposed for fifteen days, in which time it was exposed to three rains, amounting to 1.76 inches, lost sixty per cent of the protein, one-third of the fat and forty-one per cent of the nitrogen free extract.

It would seem advisable for the alfalfa grower to provide himself with hay caps, sufficient to cover the hay on a part of his acreage. These should be made of factory, or similar cloth, about six feet square and will cost about fifty or sixty cents each, exclusive of the labor of making. These may be used several times for each cutting.

A word of caution may be in place here against putting the alfalfa in the mow or large stack until thoroughly cured. Loss by spontaneous combustion is much more apt to result from storing uncured alfalfa than in the case of a grass or mixed hay. If the hay is cured in the cock, it goes through a natural process of sweating and usually will be in good condition to go into the mow, but the hay which is cured in the swath and windrow is apt to contain a large amount of moisture in the stalks which make it unsafe to put in the barn.

Many methods of handling and storing alfalfa, such as baling in the field, storing green in open sheds, putting in the silo, etc., are being used or tried in various sections, but the only method that seems to be suited to general recommendation in Michigan is the storing of the cured hay in barns or fairly large stacks. Alfalfa may be made into a fairly good, but rather sour ensilage, but the crop is not sufficiently improved in feeding value to justify this method as a general farm

practice. It is questionable even whether the first cutting, which is made at a time when the weather is apt to be unfavorable for curing, may with profit be placed in the silo. However, the last cutting may, to advantage, be mixed with corn, if the weather does not permit it to be made into a good grade of hay. Ensilage made by mixing one load of alfalfa hay with two or three loads of corn would be of higher feeding value than ensilage made from corn alone.

FEEDING VALUE OF ALFALFA HAY.

No attempt will here be made to go into an elaborate discussion of the feeding value of alfalfa hay. In looking over the reports, however, it has been interesting to note that not a single alfalfa grower has any complaint to make in regard to the feeding value of alfalfa hay and practically all who have expressed an opinion consider it very valuable. Of the 97 growers making a comparison with clover, 12.3 per cent consider the hay worth twice as much as clover; 14.4 per cent one and one-half times as much as clover; 5.1 per cent one and one-third times as much as clover; 10.3 per cent one and one-fourth times as much as clover and 50.6 per cent state that it is better than clover. Alfalfa hay appears to have a feeding value above what its composition would indicate, as all kinds of stock do exceptionally well on it. Even hogs, which are not supposed to be able to handle any large quantity of rough feed, do well on alfalfa hay as the main part of the maintenance ration. Because of its high protein content, it is especially valuable as a feed for dairy cows, for breeding animals and for growing young stock. It is of considerable economic value when grown and fed on the farm, as it takes the place of high-priced protein-rich concentrates, such as bran and cotton seed meal, which have of late years entered so largely into the feeding problems in this state. It is more economical under most conditions at least, to feed it as a part ration either with corn or some carbohydrate roughness, as corn stover or grass hay, rather than to feed it alone.

ALFALFA AS A PASTURE CROP.

Two hundred fifteen or about thirty-eight per cent of the alfalfa growers report having used alfalfa for pasture purposes. These tests have been made with all kinds of stock and under various conditions of pasture, season, etc. Twenty per cent of these growers fail to say with what results they have used alfalfa as a pasture crop. The results from the other eighty per cent, who expressed an opinion in regard to this point, are presented in tabular form below.

TABLE XVI.—RESULTS OF PASTURING ALFALFA.

	No. of reports.	Good results, per cent.	Medium results, per cent.	Poor results, per cent.
Horses	19	100.0	0	0
Cattle and sheep	81	90.1	3.7	6.2
Hogs	75	97.3	1.3	1.3
Poultry	2	100.0	0	0
Total	177	....	....	....

While many of the reports included in the above table are based upon quite limited experience, the data, as a whole, indicates strongly the value of alfalfa as a pasture crop. Practically all of the reports are favorable so far as the effect upon the stock is concerned, only three farmers reporting trouble of bloating of cattle or sheep. Sixteen indicate injury to the stand of alfalfa.

In other states much trouble has been experienced with bloating of cattle and sheep when pastured on alfalfa. The exact conditions which cause this trouble have not been well determined, but the danger appears

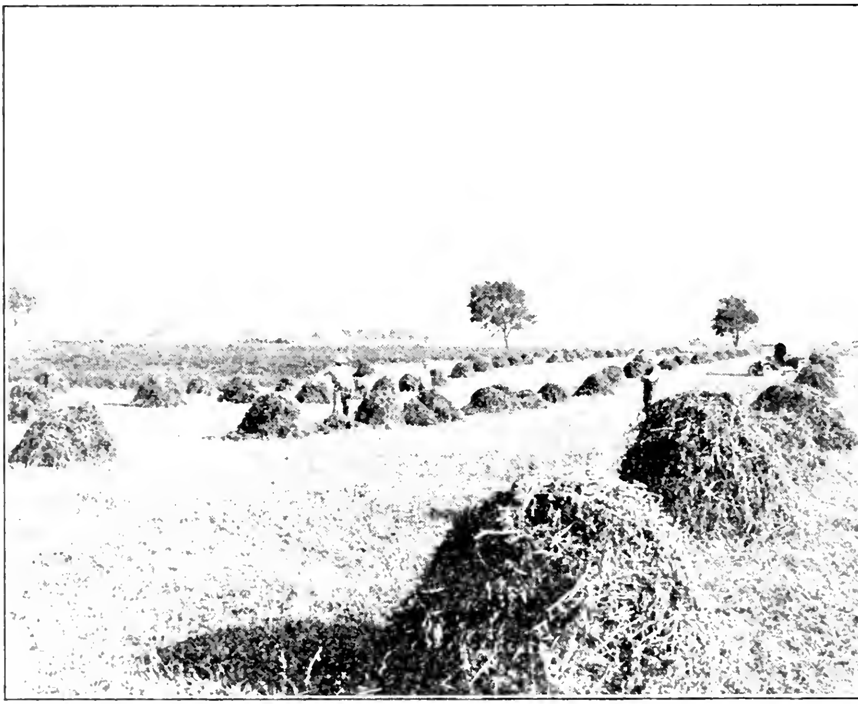

Fig. VIII. A profitable field of alfalfa in Kalamazoo County.

to be the greatest when the growth is rankest, when no other feed is given to stock, when the stock are turned in when hungry and are allowed to eat all they want when the alfalfa is wet with dew or rain. It is well established that under certain conditions alfalfa is a very dangerous pasture crop for cattle and sheep and farmers are cautioned to exercise much care in turning these classes of stock into a good growth of alfalfa. Little faith should be placed in most of the plans suggested for avoiding this trouble, but the following seem fairly reliable: Sow some grass, preferably orchard grass, with the alfalfa, so that not more than one-half of the herbage will be alfalfa. The stock prefer a variety and will eat the grass with the alfalfa, which will largely, if not entirely do away with the bloating. If late in the season the herbage becomes mostly alfalfa, it is advisable to remove the cattle and sheep from the field.

Another method which has been tried with good results is to feed the stock with enough other rough feed before turning into the alfalfa. so that they will eat rather sparingly of the green alfalfa.

Alfalfa makes an ideal pasture crop for hogs and poultry and if properly managed is very satisfactory for horses and mules. Because of its nutritive qualities and the satisfactory growth throughout the entire season, these classes of stock will thrive well on alfalfa pasture and a certain amount of stock can be kept on a much smaller acreage probably, than any other pasture crop suited to Michigan conditions.

The alfalfa pasture should be managed quite differently from the common practice with grass pastures, that is, it should not be kept eaten down closely throughout the season. This will kill many of the plants and present favorable conditions for grasses and other weeds to come in and take possession of the field. The best management, probably, would be to have several lots and to turn enough stock into a lot to eat off the growth in a short time and then to turn the stock into a new field. If only one field is available the alfalfa should be kept from six to ten inches or more high all the time, or if eaten down closely, the stock should be turned out long enough for the alfalfa to make a renewed growth. Alfalfa because it does not propagate vegatively, because it is not inclined to spread over the ground and because it does not thrive continuously under close cropping, is not an ideal pasture plant. It will produce more when cut for hay or soiling than when used as pasture. Still because of its productiveness and nutritive qualities, it ranks well as a pasture crop, especially when mixed with some of the better grasses and clovers and it is recommended that it be generally seeded in this way for pasture, under soil conditions that are favorable for its development.

ALFALFA SEED PRODUCTION.

A very small percentage of the alfalfa growers of the state have attempted to grow alfalfa seed, most of them having been content with the growing of the crop for forage purposes. The success, however, with which the few have grown seed and the amount of seed commonly produced by scattered plants which have not been mown for hay, indicate that Michigan conditions are very favorable for the production of alfalfa seed. The following conditions seem to favor the production of seed; rather dry, sunshiny weather from the beginning of bloom until the maturity of seed; soils that are rather light and of only medium fertility, such as many of our sandy soils; and the thin stands which will allow the wind and sunlight to strike the sides of the plants as well as the tops. If alfalfa is grown primarily for the seed, it should be planted in rows about twenty-eight or thirty inches apart and cultivated. The demand for home grown seed should make this a very profitable enterprise on the lighter types of soils. Profitable crops of alfalfa seed may, however, be produced under certain conditions in the thickly seeded fields. The second crop of the season is the one to save for seed in Michigan, as this allows the cutting of one hay crop and presents more favorable weather conditions for the filling of the seed crop. The third cutting develops too late in the season to mature the maximum amount of seed.

Alfalfa has a long period of bloom and some of the earlier pods mature long before the later pods, so that it is sometimes difficult to determine the best time to harvest the crop. The harvesting should be done at the time that will permit the saving of the largest amount of well matured seed. Usually this is shortly before the earliest pods begin to shatter their seeds and when about one-half to three-fourths of the pods are brown. The harvesting of the seed crop should not differ materially from the harvesting of clover seed, the most important consideration being to handle the crop in such a way as to prevent the shattering of the seed. The cutting should be done when the alfalfa is somewhat toughened by dew. A self-rake reaper or mower with a side delivery attachment should be used to prevent the team from tramping out the seed. The crop should be handled as little as possible and should preferably be stacked before dry enough to lose any seed and be allowed to remain in the stack for several weeks before threshing but may be placed in small bunches while in a tough condition and threshed from the field if the weather is favorable.

PLACE FOR ALFALFA ON THE FARM.

Aside from its value as a soil improver there are three important places that alfalfa may occupy on the Michigan farm, as follows: Seeded alone as a hay crop; seeded alone as a pasture crop for hogs and under certain conditions for other classes of stock, and for mixing with the grasses and clovers for meadows and pastures for all kinds of stock.

Under soil conditions favorable for the growing of this crop, it is generally advisable to use the alfalfa for all three of these purposes. A good stand of alfalfa may be expected to produce more hay than any of the grasses or clovers and the annual risk and expense of seeding is largely done away with. Every general or stock farmer should seed a small acreage near the barn as a pasture for hogs. On many farms a portion of the soil is only fairly well suited to the growing of alfalfa besides some of the grasses should be seeded to produce a hay for the horses and to avoid the danger of bloating when used for pasture, so that it does not seem practicable to devote all of the seeded area of the farm to alfalfa. Even under these conditions alfalfa if seeded with some of the grasses and clovers usually proves to be a very valuable part of the mixture. The seeding alone of a large acreage at the first attempt is not recommended, as the risk of failure in the hands of the inexperienced grower is too great, but the alfalfa seed should be mixed with the regular seeding of clover as suggested above and should also be seeded alone on a small acreage and this increased from year to year until the desired acreage is secured.

Alfalfa is a leguminous plant, and closely related to the clovers, cow peas, beans, etc., and like them is able with the aid of the bacteria which live in the nodules on the roots to take its supply of nitrogen from the atmosphere. It thus improves the soil in the same way clover does. However, after the alfalfa has been seeded in the field for several years and the nitrogen content of the soil increased by the decay of roots, nodules, stubble, leaves, etc., the crop will feed on the nitrates made from this source and will take a smaller percentage of its nitrogen from the atmosphere. The alfalfa then does not do as much to build up

the nitrogen content of the soil after it has been grown for several years in a field as it does during the first two or three years after seeding. It is, therefore, not advisable to leave one field seeded for an indefinite period of years, or as long as it produces satisfactorily as is commonly done, but to seed a new field which needs building up and to plow up the old field which should be in condition to produce very satisfactory yields of corn and other crops.

This would necessitate the inclusion of alfalfa in the rotation of crops and bring about other radical changes in the rotations as commonly practiced throughout the state.

Fig. IX. A field of alfalfa and orchard grass on the college farm, which has produced an average yield of 6 tons per acre during the past 5 years. Orchard grass is one of the best grasses for mixing with alfalfa for pasture or to produce a hay for horses.

The rotation of crops suited to a particular farm will depend upon the type of soil and the adaptability of the various crops to the same; the type of farming engaged in; the markets and other local factors. No detailed plans of rotations of crops are presented in this bulletin but the following suggestions are offered as being worthy of consideration: The best plan of carrying out a definite rotation including the alfalfa, is the short rotation of annual crops inside the long or complete rotation, that is, the alfalfa is left seeded in one field for a short period of years and the remainder of the farm devoted to the short rotation. After a few years the old field of alfalfa is plowed up and devoted to the short rotation and alfalfa seeded in a new field.

The short rotation of annual crops should be one that is favorable to keeping up the fertility of the land. If clover is not needed for the production of hay on account of the alfalfa, it or some other legume should be seeded for plowing under.

The best management probably would be to leave the alfalfa seeded in each field from three to six years. The cost and risk of seeding is materially increased if alfalfa fields are left less than three years and the leaving of a seeding more than six years would not seem to be the most economical use of it as a soil builder for the entire farm, since it would take so long to get the entire farm seeded.

It is advisable to seed at least one-half of the new field before plowing up the old field if the latter is still in a productive condition.

A good idea of the results with which alfalfa has been seeded in Michigan during the past few years may be had by the study of Table XVII. It should be noted that out of 621 trials 85.3 per cent were good or medium.

TABLE XVII.—RESULTS OF SEEDING ALFALFA IN MICHIGAN.

Total number of farmers reports	621
Per centage who seeded with good results	68.8
Percentage who seeded with medium results	16.5
Percentage who seeded with poor results	8.7
Percentage whose seedings resulted in failure	5.9

In Table XVIII is given a summary of farmers' opinions of alfalfa as a farm crop in their respective sections.

TABLE XVIII.—FARMERS OPINIONS OF ALFALFA.

Total number of farmers reports	642
Percentage who have good opinion of alfalfa	77.4
Percentage who have a fair opinion of alfalfa	14 6
Percentage who have a poor opinion of alfalfa	3.7
Percentage who think alfalfa a failure	3.2

The average acreage per field as shown by the reports is approximately six, and the acreage per farm is eight. Many farmers, however, are now seeding much larger fields than formerly, and the above figures will doubtless fail considerably of representing true conditions after one or two more seasons.

As a further indication of the place alfalfa is coming to occupy on the Michigan farm, the following brief statements which are thought to be representative of all of the opinions expressed are submitted.

"I think that alfalfa is worth nearly twice as much per acre as any of our other hay crops."

"It grows better each year. It will stand the grasshoppers, which were very bad this year. It lived while other clover, both new and old seedings, were killed."

"Best paying crop one can raise and also by far the best crop to feed."

"I think in time we can raise alfalfa just as we do clover now, but is slow in starting."

"It is the best paying crop we have."

"Some have been successful and others have failed. If we can get it established, it will be a grand forage crop."

"I think it will be the salvation of the farms in this community."

"Mighty hard work to start, but pays for all expense you can put on it."

"It will solve the problem of loosing the clover seeding, which frequently happens here. I believe in time it will be very commonly grown and will raise the value of any land seeded."

"I believe that it is all right, but it seems to take longer to get a paying stand than clover and therefore, does not work in good in the rotation."

"I think if we can get to growing our own seed nothing can equal it."

"Invaluable! There should be thousands of acres in this country where there is but one grown now. It will revolutionize agriculture."

"I think it will be the most reliable grass crop that we can raise in Southern Michigan."

"A very profitable crop if the farmer will put out only what he can take proper care of."

"A promising crop if the farmer will take pains enough in fitting his ground. I think it is one of the best hay crops Michigan farmers can produce."

"The surest and best hay known. Unexcelled for dairy calves and eaten by all stock readily."

"My intentions are to cut red clover out and make a success of alfalfa."

"I believe it will be a successful crop and the means of making our light land valuable."

"Very valuable to me to cut and feed green, as it furnished feed continuously from May 15 to October 15."

"It will solve the problem of loosing clover seeding."

"It would be a good crop if sown and taken care of on fields where there is good drainage."

"I wish I had fifty acres instead of six."

"A very good pasture for hogs."

"Good, cannot be beat for hay for all stock."

"No better than mammoth clover, of which we can get two cuttings by cutting as first blossoms appear."

"A success on good soil but a failure on poor soil."

"The best hay in the world. Believe it will be a successful crop and the means of making our light land valuable."

"I think it has come to stay. I have twenty-seven acres of alfalfa and expect to have one hundred before long."

"We think it is the making of this part of the country. We expect to get our usual amount of hay off one third the acreage and it is a better grade of hay."

"I think it is one of the greatest crops we can raise as it stands drouth better than other crops."

"For the dairy business of this section it is practically necessary as a hay crop and for keeping down the cost of the dairy output."

"It has not given very good satisfaction in this section."

"It is worth each year the price of the land."

"It is a great yielder of very nutritious hay, which all stock will go to in preference to grain."

"I think alfalfa will grow in any place in the state, seeing that it grew here."

"I have been trying to grow alfalfa for some time but will have to report a failure."

"Alfalfa is a very valuable crop for this section as quite a little stock is kept."

PARTIAL SUMMARY.

1. Alfalfa is rapidly coming into favor as a farm crop in Michigan, ninety-two per cent of the farmers reporting, expressing a good or medium opinion of alfalfa as a farm crop in their respective sections. More successful seedings have probably been made during the past three or four years than in all the previous history of alfalfa in Michigan. Many growers who have been successful in former attempts to grow alfalfa are now seeding much larger acreages.

2. The two principal causes of failure in growing alfalfa have been poor preparation of the seed bed and the lack of inoculation. A decided improvement, however, is noticeable in the cultural methods practiced throughout the state and in practically all the new seedings some means are taken of securing an inoculation of nitrogen fixing bacteria. Among other important causes of failure are acid soils, light infertile soils, poorly drained soils, use of nurse crop and in case of late seedings, winter killing.

3. Alfalfa is being grown successfully on a variety of soil types throughout the state. The particular type of soil does not appear to be of much importance but soils that are shallow by reason of the water table or rock formation near the surface and very light infertile soils should be avoided. Farmers on light sandy soils should seed on their best land and may need to take some special means of building up the fertility of the soil. Farmers in the better agricultural sections should as a rule seed on the higher lands of the farm because this land is most in need of improvement; because the alfalfa as a rule is productive on this land and because the soil most productive with corn and other crops is left for the growing of these crops.

4. Alfalfa should not be seeded after a grass sod but may follow a cultivated or small grain crop. The preparation of the seed bed should be thorough and extend over a period of several weeks, so as to secure a firm and finely pulverized seed bed in which the weeds and weed seeds have been as completely eradicated as possible.

5. The use of manure in seeding alfalfa is advisable if applied some time before seeding or after the alfalfa has come up and made some little growth. It is not advisable to turn under a heavy application in a quickly prepared seed bed as this tends to hold up the soil and allow it to dry out, or to apply as a top dressing shortly before seeding, because of the introduction of the weed seeds.

6. There are doubtless many conditions under which commercial fertilizers judiciously applied, may profitably be used to stimulate a more vigorous growth both in the new and old seedings but the idea that is more or less prevalent that commercial fertilizers may be used to immediately make any soil productive is a fallacy, and until further data is available at least, commercial fertilizers should be applied in an experimental way to learn what may best be used under local conditions.

7. On many soils throughout the state lime does not seem to be needed but on others it is quite essential to the successful growing of alfalfa. It is well to apply lime on a portion of the field when seeding alfalfa for the first time, especially if difficulty has been experienced in growing clover, or if there is any other indication of an acid soil.

8. The presence of nitrogen fixing bacteria is of utmost importance in the growing of alfalfa. Both the soil and pure culture methods of inoculation have given good results and one or both should always be used whenever alfalfa is being seeded for the first time in a field.

9. The exact date of seeding is not of so much importance as the preparation of a good seed bed and several other factors. Late spring or early summer is a favorable time on the medium or heavy types of soils, and early or middle spring is a good time on the lighter types of soils.

10. The use of a nurse crop is not advisable except on fields that are apt to blow or wash and on seed beds that are poorly prepared and are apt to become very weedy.

11. If a drill is used judiciously this method of seeding is preferable to broadcasting and harrowing in but care should be exercised to see that the seed is covered to the proper depth.

12. The rate of seeding within certain limits is not an important factor in the seeding of alfalfa. A very light seeding is satisfactory under ideal conditions. Ten or twelve pounds per acre should ordinarily be as good as more and is a safe amount for general recommendation.

13. There are no commercial varieties of alfalfa in the sense that we have varieties of corn, wheat, etc. For general use we must depend mainly upon the American grown seed of the common or the blue flowered alfalfa, though the Grimm and other selections of the variegated alfalfa are very desirable for planting under Michigan conditions. Northern grown seed should be purchased in preference to that grown in the central and southern states.

14. New seedings of alfalfa should be clipped often enough to hold the weeds in check but not usually more than two or three times during the first season.

15. The harrowing of alfalfa during the first two or three years after seeding is not advisable. Old stands that are thin and weedy are frequently improved by this treatment.

16. The alfalfa leaf spot is a more or less common disease of alfalfa but is not usually considered serious. Fields that are badly affected should be mown, when if the weather conditions are favorable the alfalfa will usually make its normal growth.

17. Much care should be exercised in the purchase of seed to avoid the introduction of noxious weed seeds on the farm. If dodder is introduced it should be thoroughly eradicated before it goes to seed even at the expense of destroying the stand of alfalfa.

18. The better methods of making alfalfa hay are quite different from those commonly practiced in the curing of mixed hay and should be given considerable study on the part of the inexperienced alfalfa grower.

19. Alfalfa hay is considered generally to be of very high feeding value. Of those growers making a comparison with clover hay 92.7 per cent consider it better than clover.

20. Alfalfa is not well suited to stand close cropping and the tramp-

ing of stock but still is a most valuable pasture for hogs and under certain conditions and treatments for other classes of stock.

21. Little alfalfa seed has yet been produced in Michigan but there is promise that a seed industry of considerable importance may be developed in the state on account of the adaptability of many of our soils to alfalfa seed production.

22. Alfalfa should be seeded on practically every farm, all or a portion of which is well drained, throughout the agricultural sections of the state. Its special places in Michigan agriculture are, seeded alone as a hay crop, seeded alone as a pasture for hogs, and as a perennial legume for mixing with clovers and grasses for both hay and pasture.

23. It is not advisable to seed a large acreage of alfalfa at the first attempt. A small acreage should be seeded under as favorable conditions as possible and this increased after some experience has been gained in growing this crop.

24. The profit from the entire farm will be increased if alfalfa is reseeded in a new field every four to six years as compared with leaving the same field seeded for any definite period. The best plan for a rotation of crops including alfalfa is the short rotation of the annual crops inside the long or complete rotation.

ACKNOWLEDGMENTS.

Mr. A. R. Potts, Field Agent of the department, having visited hundreds of alfalfa fields throughout the state during the past three seasons, has given valuable assistance in the study of local conditions and the gathering of data for this bulletin. Mr. F. A. Spragg and Mr. R. G. Hoopingarner have assisted in the preparation of a portion of the tabular data. Several of the Station staff have given valuable assistance in the revision of the manuscript. All of which is gratefully acknowledged by the author.

FOREWORD.

Special Bulletin No. 59.

This bulletin has been prepared to meet the demands for brief practical information on the culture of small fruits in Michigan.

The author, Mr. Wilkin, has for several years been the Superintendent of the Sub-Experiment Station at South Haven, and he writes from practical experience.

H. J. EUSTACE,
Horticulturist.

SMALL FRUIT CULTURE.

BY F. A. WILKIN.

The profits from small fruits are fully equal to those from tree fruits but as with all fruits, they range from almost nothing to as much as $1,500 per acre in some cases. General care or culture is the most important factor that determines the profits of all small fruits and marketing is undoubtedly next in importance.

The objection to small fruits is that they are very perishable and have to be produced within a short shipping distance from good markets. They are soft, (gooseberries and currants excepted) and must have very careful handling.

STRAWBERRIES.

The strawberry is the most important of the small fruits and by many is considered to be the choicest of all the fruits.

SOIL AND ITS PREPARATION.

The best soil for strawberries is that which is cool and moist but well drained and easily worked. Strawberries are shallow rooted plants and do the best in soils in which the moisture and fertility are near the surface. However, almost any soil that is suitable for corn or potatoes may be used for strawberries, after the proper preparation.

Thorough preparation of the ground for a strawberry bed is very essential. If it is very weedy or in a heavy sod it is advisable to plow it in the fall and work it thoroughly in spring or better still, plant it to some hoed crop as corn or potatoes the year before setting. It is also very necessary to have the soil thoroughly pulverized and the sod, if any, thoroughly broken up. After the ground is well worked, it is advisable to roll it, as this operation pulverizes it and leaves the surface smooth for marking and planting.

The best time to fertilize a strawberry plantation is before the plants are set. Well rotted manure, not infested with white grub and spread on before the ground is plowed is the best. This may be supplemented with muriate of potash and acid phosphate, as suggested under "Gooseberries." If the soil is thought to be lacking in nitrogen, one hundred pounds of nitrate of soda may be applied on the young plantation twice, just as the young plants become established and again three weeks later, to hasten the growth of the plants. However, this is rarely necessary if proper preparation has been given the soil.

PLANTS AND PLANTING.

The best plants are dug from one year old plantations that have not borne fruit. Those dug from bearing beds are likely to lack in vigor.

It is the best plan to have the field ready for setting as soon as the plants are dug or received from the nurseryman. If it is necessary to "heel in" the plants, the bunches should be opened and the plants placed in layers of about two inches thick. The soil should be firmly pressed around the roots as high as the crowns and they should be watered as necessary so that the roots will not dry out. If watered too much, the plants will heat and be injured.

Before setting, the roots should be trimmed back to about three inches and all of the leaves but one or two of the youngest should be pruned off. It is quite essential to have the roots moist when setting and some growers carry a pail partly filled with water in which they dip the roots just before planting. The best tools for setting are a dibble or a spade, either is pushed into the ground and then forced from side to side, leaving an opening in which to place the plant. The dibble is handy if one man is doing the planting but a spade is better where two men work together and one man makes the holes and firms the soil around the plants while the other trims and places them in the holes. In planting, the roots should be spread out and the soil firmly pressed around them and the crowns should come even with the surface of the ground.

CULTIVATION.

The cultivation should be started very soon after the plants are set and care must be taken not to cultivate too deeply nor to disturb the roots or cover the crowns. Frequent shallow cultivation should be practiced throughout the entire growing season, never allowing the surface of the soil to crust over. The dryer the season or location, the shallower the cultivation should be and if the season or the location is excessively moist the cultivation should be deeper.

There are three distinct methods of culture of the strawberry, the matted row, the hedge row and the hill system and there are also variations of these three types.

The matted row is the most common method and it is the least intensive. The wider the row the less intensive the method. Generally the wide matted row is allowed to grow from one foot to one and one-half feet wide with about one foot space between the rows for the pickers. The narrow matted row is from six inches to one foot wide and with a wider space between the rows.

The hedge row system consists of setting the plants close together and allowing the runners to grow only in the spaces between these plants and, when the space is filled with plants, all other runners are cut off. Thus the row should not be wider than the space occupied by one plant.

In the hill system, the plants are set quite close together and no runners allowed to grow. This is the most intensive system as all the vitality of the plant goes into producing fruit buds. The fruit is generally of exceptional size and quality and each plant produces a large number of berries. This system should be used if the finest berries are desired.

The distance for setting the plants depends upon the system and the variety used. In the matted row system, the rows should be three and one-half feet apart and the plants set two feet apart in the row. Varieties that make numerous runners, such as the Dunlap, can be set farther apart in the row, while the varieties that make but few runners should be set closer together.

For the hedge row and hill system, the plants should be set one and one-half feet apart, in rows one and one-half to two feet apart. In the hill system one and one-half feet is sufficient. A greater distance would not be economy of ground. It is advisable to use varieties that do not make very many runners for the hedge row and hill systems.

The narrow matted row, is the best for general strawberry growing. It is the most commonly used and does not need the extra work and special care to make it a success that the more intensive methods do.

It is advisable to cut off all the runners from the newly set plants about the middle of June so that the plants may become strong and well established. All the blossoms should be cut off during the first season.

MULCHING.

After the growth has stopped in the fall and before the ground freezes hard, the plantation should be covered with some mulching material. Straw is commonly used for this purpose but almost anything will do if it is free from weed seeds. Marsh hay is excellent. Stable manure is not advisable as it almost always contains weed seeds.

As soon as the growth starts in the spring the mulch should be taken off from the plants and left between the rows. This will help to keep the fruit clean at ripening time and also conserve the soil moisture. If the plantation is in a frosty place, it is well to only take off a portion of the mulch at first, leaving enough to check the plants but not enough to smother them. After the danger from frosts is past this can be taken off or the plants may be allowed to grow up through it. If it is desirable to hasten the ripening of the fruit, it is best to take the mulching off, or if late ripening is desired, let the plants grow up through it.

During the ripening period, it is advisable to have the mulching close to the plants along the edges of the rows so the berries on the outside plants will rest upon the mulching intead of on the ground.

RENEWING PLANTATIONS.

Many growers allow the plantation to bear only one season, as they believe the cost of renewing an old bed is almost as great as starting a

new one. This is certainly true with the old beds that have been allowed to become foul with weeds, diseases and insects. The beds that are renewed every year do not often become seriously infested with pests as do the beds that are left several years.

If it is considered advisable to renew the old bed, the following method has been found to be satisfactory. After the fruit has been picked, mow off the tops of the plants and loosen the mulch so that it will dry out well. When all is thoroughly dried so as to burn rapidly and the wind is in a favorable direction, start a small fire at the windward side and allow it to burn as quickly as possible; as slow burning may injure the crowns of the plants. This will burn all of the old foliage and mulching and will destroy the source of many insect and fungous troubles.

After the burning has been completed, the rows should be narrowed to about the width of one plant by plowing away from them on both sides. Then the rows should be gone over with a hoe and all the old plants and weeds hoed out and the ridges left by plowing should be worked down and the soil brought back to the rows. If the weather is dry, this work should be done immediately so as to keep the plants from drying out. With proper burning over and the other work done quickly afterward, the bed will not be injured in the least. Cultivate frequently to keep down weeds and prevent the soil from baking. It is rarely profitable to retain a bed after more than its second bearing season.

CONTROLLING INSECTS AND DISEASES.

Before setting out the young plants look them over carefully and remove any discolored or diseased leaves. Examine the roots for root lice, if any are found or are suspected, dip the roots in strong tobacco water.

After the growth starts, spray with Bordeaux* and a poison† to prevent the leaf spot and to destroy the leaf-roller insect that may be present.

For fruiting plantations, spray with Bordeaux before blossoming and repeat ten days to two weeks later. After fruiting if the bed is to be fruited again, mow and burn over quickly (as on a day when there is a wind, to avoid burning the crowns of the plants). If leaf rollers have been present, spray with poison after the growth has started again but before the leaves curl.

For strawberry root lice, see Michigan Bulletin No. 244 page 88.

White grubs often cause serious trouble in strawberry beds. After they get in the soil, nothing can be done to destroy them except digging them out by hand which is not practical. Since sod ground and manure piles are favorable breeding places it would not be advisable to plant strawberries on sod ground and manure produced before the first of August or left uncovered until then should not be used. Late fall plowing will greatly reduce the number of grubs in a soil already infested.

It is difficult to recommend varieties of strawberries as they are very

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*Bordeaux mixture, 4 pounds of copper sulphate, 5 pounds of stone lime and 50 gallons of water.

†With ½ pound of Paris Green or 2 pounds of arsenate of lead.

VARIETIES.

sensitive to different soil types and conditions. A variety might be the best that could be grown upon one type of soil and be a failure on another in the same locality.

In a general way, varieties of the type that have fairly large leaves which are quite smooth and of a dark glossy green color, producing few runners and bearing fruit of fine appearance and of high quality of which Marshall is an example, should be grown upon a fairly heavy soil. Varieties having large coarse-wrinkly leaves, mottled green in color, which make a fair amount of runners, and produce a soft, usually furrowed wedge shaped fruit, not of very high quality but of good size as the Dorman, can be grown on the lighter soils. Varieties like the Senator Dunlap, having small plants making numerous runners and producing berries of moderate size, good color, shape and quality do well upon a greater variety of soils than the others.

For early varieties, Michael's Early, August Luther and Excelsior are good. For medium early to mid-season varieties: Senator Dunlap, Clyde, Bederwood, Warfield, Glen Mary, Ekey, Haverland, Kitty Rice, Bubach, William Belt, and Dorman (Uncle Jim). For mid-season to late: Aroma, Brandywine, Ridgeway, Sample, Stevens' Late, Chesapeake and Marshall.

Varieties that are heavy bearers but with rather soft fruit and which do well on the lighter soils are: Clyde, Bederwood and Dorman. Those that make numerous runners and bear heavily are Senator Dunlap, Warfield and Buster. Marshall, Chesapeak, Ridgeway, Kitty Rice, Wm. Belt, Bubach and Cardinal make but few runners or plants and bear moderate crops of high quality fruit and are desirable for hedge row and hill systems. They require rich soil and should set close together in matted rows.

It is important to understand the difference between perfect and imperfect blossoms. The varieties with perfect blossoms, having both the sex organs in the same flower, will produce fruit if planted by themselves, but varieties with imperfect blossoms lack the male sex organs and must be planted near a variety having perfect flowers to produce fruit. If varieties with imperfect blossoms are to be planted, it is advisable to plant some variety having perfect blossoms in every fourth or fifth row for pollination.

The following varities have perfect blossoms: Michael's Early, August Luther, Excelsior, Senator Dunlap, Clyde, Bederwood, Glen Mary, Ekey, Wm. Belt, Buster, Dorman, Aroma, Brandywine, Ridgeway, Steven's Late, Chesapeake and Marshall.

The following have imperfect blossoms and need others to fertilize them: Warfield, Haverland, Bubach and Sample.

In every catalogue the sex of the variety is always given together with the general description.

TEST PLOT.

New varieties are constantly appearing in the catalogues and for the grower who may possibly wish to introduce any of these into his

plantations, it is advisable to have a test plot. This plot should be located where the soil is most characteristic of the commercial plantation. Twenty-five plants of a variety will suffice for testing. By such a test plot a grower can find which varieties are suitable for his farm and at but slight expense.

GOOSEBERRIES.

The second earliest fruit ready for market is the gooseberry. It is principally a pie fruit and is usually preserved for such purposes. Its market is more limited than that for the strawberry, but it is not nearly as perishable and can be picked and used at various stages of maturity. At present the demand does not equal the supply. More of this fruit is being commercially preserved every year and this use should take care of an increasing supply for many years. However, due to the high price of plants comparatively few gooseberry plantations have been planted during the past few years.

The care of the gooseberry is not as exacting as the strawberry, but good care pays and the profits are good, sometimes being as high as several hundred dollars per acre. A well drained, moderately rich soil or one that will grow good corn will be suitable for gooseberries. The location should be sunny and there must be a good circulation of air on account of the susceptibility of the fruit and foliage to a fungous disease known as the mildew. The ground should be well fitted and fertilized before the plants are set out. But fertilizer can be applied more easily to gooseberries after the plants are set than can be done with strawberries.

PLANTS AND PLANTING.

Two year old plants are generally planted and usually sold by the nurserymen but one year old plants that have made a good strong growth will do. The plants are usually set in rows six feet apart and four feet in the row. If the roots are very long, it is advisable to trim them back slightly. The plants should be set slightly deeper than they were in the nursery, especially on a light soil and the roots spread out as much as possible and then the soil firmed about them.

CULTIVATION.

The cultivation of gooseberry plants should be thorough and started early in the spring and continued until about the first of August when a cover crop, preferably oats, should be sown. An application of well rotted stable manure before cultivation starts will undoubtedly pay well and this might be supplemented with an application of one hundred to two hundred pounds of muriate of potash and two hundred to five hundred pounds of acid phosphate per acre.

PRUNING.

The pruning of the gooseberry plant is important. When the plants are set the tops should be cut back slightly and the bush balanced up as much as possible. A good bush should have about six bearing canes. The tops of each cane should be cut back slightly each year and the

season's growth cut back a little, depending upon the growth made. The young shoots not needed should be cut out every year. A few of the stronger ones should be left to replace the older bearing canes. The gooseberry bears its best fruit on canes from two to four years old and by leaving one or two of the stronger young shoots each year and cutting out one or two of the old ones, the bearing wood can be kept in the best condition.

In pruning it is highly important to keep on the lookout for the cane borer which is a little worm that bores in the center or pith of the cane. This worm almost always works downward. A cane with a black center and somewhat hollow indicates the work of the borer and such a cane should be cut back until the sound healthy pith is reached.

CONTROLLING INSECTS AND DISEASES.

Gooseberry bushes should be frequently inspected for San Jose scale or the European fruit scale, especially in localities where these insects are known to be common. They can be destroyed by spraying the bushes early in the spring before growth starts with the *strong* lime sulphur.

The mildew (a common and serious fungous disease especially of the English varieties) and leaf spot diseases and "worms" can be controlled with the *dilute* lime sulphur or Bordeaux to which is added 2 pounds of arsenate of lead to every 50 gallons. Make the first spraying just as the leaves are expanding and again when the fruit is about one-fourth grown.

If the mildew is serious or the varieties are English use the *dilute* lime sulphur without arsenate of lead every 10 or 12 days.

If worms are found after the fruit is one-fourth grown poison them with pyrethrum or hellebore..

Leaf bugs or aphids may appear. When they do, spray with nicotine or strong tobacco water while the bugs are red and wingless and before the leaves have become curled.

When pruning, if a cane is cut that shows discolored pith, it may indicate the cane borer. Cut back to sound pith. Burn trimmings.

Wilted foliage at any time indicates the cane borer. Cut out and burn.

VARIETIES.

The following American varieties have been found to be comparatively free from the mildew:

DOWNING is the most valuable variety grown for commercial purposes. It is vigorous and productive. The fruit is of good size and of yellowish green color. It will not stand neglect as well as some other varieties.

HOUGHTON is second in value on account of its vigor, freedom from disease and ability to withstand lack of care. Its growth is more slender and spreading than that of the Downing. It is very productive but the fruit is not as large nor as attractive as that of the Downing.

RED JACKET AND PEARL are two varieties quite commonly planted. Red Jacket is vigorous and prolific, its berries are good sized and red when ripe. The reddish tinge makes them undesirable for market purposes. The Pearl is a cross between the Downing and English variety

and so nearly like the Downing that it is difficult to distinguish between them.

The English varieties are not grown very extensively in this country on account of their extreme susceptibility to mildew. They are often shy bearers, but the fruit of most of the varieties is large and of attractive appearance. Where there is a market for fancy gooseberries, they will bring a good price. The following varieties are considered the best:

Chautauqua.—The bush is vigorous and productive, fruit very large, pale green in color and of high quality. Valuable for home use.

Columbus.—Bush vigorous, fruit somewhat like that of the Chautauqua. It is not as susceptible to mildew as some of the other varieties.

Industry.—Bush vigorous, most productive of the English varieties. Fruit is very large and dark red when ripe and quite hairy. One of the best English sorts, although the reddish color is somewhat against it.

Portage is one of the newer varieties. It is an American raised seedling of a European variety. It is vigorous, productive and hardy. The fruit is pale green, smooth and attractive, nearly as large as that of the Chautauqua and probably averages about half way between the Downing and the Chautauqua. It is practically as free from mildew as the American varieties.

RAISING PLANTS.

Gooseberry plants are not difficult to raise by the following method: Make cuttings of the past season's wood, either in fall or early spring, about eight inches long and of well ripened wood. If cut in the fall, they are most easily handled by tying them in bundles, labeling and packing them in *damp* sand or moss in a *cool* cellar. Early in spring, they should be planted in nursery rows, leaving two buds above the ground. It is essential to get the cuttings planted before the growth starts and good cultivation should be given them during the season.

CURRANTS.

The planting, culture, pruning, and propagation of the currant is the same as that of the gooseberry. The location of the currant plantation should, however, be somewhat different from that of the gooseberry. Currants do the best in partial shade and that of a fence row or an orchard is quite desirable, but it would not be desirable to set currant bushes in an orchard unless the soil is very fertile. And the bushes should, of course, be set where they will least interfere with the usual operations in the care of the trees. Generally, it is not advisable to set currants in an old orchard, as the trees use practically all of the available plant food. Currants will thrive on a soil that is more moist than gooseberries and they do not require as free a circulation of air, since they are not susceptible to the mildew.

CONTROL OF INSECTS AND DISEASES.

The insects and diseases most common and troublesome to currant bushes, foliage and fruit can be controlled by the treatment outlined for the gooseberry on page 9.

VARIETIES.

The following varieties of currants have proven valuable in this state:

London Market. Extensively planted on account of its vigorous plant, healthy foliage and productiveness. The fruit is large and handsome. Ripens with Victoria. Well and favorably known in Michigan.

Victoria. An old time standard variety. A vigorous, erect grower and very productive. Berries are medium size and hang in large and extremely long bunches. Is being succeeded by varieties having larger berries.

Fay's Prolific. A well known market variety, on account of its productiveness, and large handsome berries. It is more productive and of better flavor than the original Cherry currant.

Wilder. A comparatively new variety. Its promising features are its strong vigorous growth and productiveness. The fruit is large and handsome and hangs on for late picking.

Red Dutch. One of the oldest varieties known and still grown by many. Its general characteristics are similar to those of Victoria, but it is distinct from it.

Prince Albert. A favorite with many growers in Michigan but it is not generally grown; a strong grower and productive; berries are medium in size and hang in short bunches; used considerably for canning.

Red Cross. A new variety. A vigorous and productive bush. Berries are large and hang in long, large clusters. Flavor mild and pleasant.

Perfection. A new variety that has gained prominence very rapidly. A vigorous grower and bears well. Well known. Large handsome fruit to the end of the bunch which are medium in size. The flavor is less acid than other varieties of the Cherry type.

The black and white currants are little grown in this State. The White Grape is the most satisfactory variety of the white fruit type.

The culture of the black currant in Michigan cannot be encouraged, since it harbors a disease that is extremely dangerous to the White pine tree. Bearing plantations should be exterminated.

RED RASPBERRIES.

The red raspberry is an important source of profit to the small fruit grower. The demand is always strong for good fruit and it is used in the fresh state and for canning and preserving. The softness of the fruit, however, makes it very essential that the market be close at hand and that the fruit be handled with extreme care. Poor prices for red raspberries are almost always due to careless handling and to their perishability.

The best soil for a red raspberry plantation is rich sandy loam, well drained but containing plenty of moisture.

PLANTS AND PLANTING.

Plants for a new plantation can easily be taken from an old bed by digging up the strong suckers of the past season's growth or, they can be secured from a nursery. The tops of the young plants should be cut back to about six or eight inches and the roots also cut back slightly.

Plants received from a nursery usually have the tops cut back sufficiently, but the roots are not trimmed. The plants should be set a little deeper than they were before and the soil well pressed about the roots. They should be set in rows five or six feet apart and three feet apart in the row.

CUT WORM.

The climbing cut worm frequently destroys a large proportion of newly set plants of raspberry and blackberry plantations. The insect eats the buds at night and during the day conceals itself in the ground near the plant. They can be destroyed by trapping or poisoning. If shingles or boards are placed on the ground near the plants, the worms will hide under them during the day and can be gathered and destroyed in the morning. The "poisoned bait" method consists in scattering on the ground a mixture of moist bran and paris green. This should be scattered in the evening as the bran will then remain moist longer. One teaspoonful of Paris green to two quarts of bran is sufficient.

PRUNING.

The red raspberry bears fruit on canes that are two years old, and a cane is of no value after it has produced one crop of fruit. These old canes should be cut out and burned immediately after the fruit is all picked. The new canes require the room and moisture that the old canes would be using after they have fruited. Five or six of the strongest young canes in a hill should be left for the next season's crop.

CONTROLLING INSECTS AND DISEASES OF RASPBERRY, BLACKBERRY AND DEWBERRY.

The source of several insect and fungous troubles will be greatly reduced by cutting out and burning the old canes immediately after the last picking.

The ORANGE RUST may appear in May or June. It is easily identified by the bright orange color on the under side of the leaves. There is no method of preventing this trouble. As soon as it is found, the bush should be dug out and burned. If allowed to remain the disease will spread and destroy many plants.

The ANTHRACNOSE, identified by the grayish spots on the canes (also on leaves but not conspicuous), is common in many berry fields. It does not yield to spraying unless very frequently done with Bordeaux mixture and this may not be profitable. If desirable, make the first spraying when the new canes are 6 to 8 inches high and repeat every two weeks during the growing season.

"WORMS" or "SLUGS" might appear at any time. Spray with an arsenical if early in season, but if near picking time, use hellebore or pyrethrum.

Cut out and burn gouty galls, tree cricket eggs or borers in stems.

VARIETIES.

CUTHBERT is the most valuable variety and is grown more than all others combined. It is a vigorous grower and is very productive of

large fruit of good quality. It is especially desirable as a commercial variety because of the firmness of the berry.

Miller's Red and Early King are very good varieties. They are both early varieties and do well on a clay loam soil.

Eaton Red is a recent introduction. It is very large, crumbles easily when ripe and does not stand shipping well. Its color is purplish red but it sometimes takes on this color before it is ripe. Its season of ripening is very long. Quality is good and it is a good berry for home use and local market. Plant is vigorous and productive.

BLACK RASPBERRIES.

The soil, planting, cultivation and spraying for the black raspberry should be the same as that of the red. The pruning is necessarily different, however, because of the different character of its growth. The black raspberry grows in stools and does not produce suckers, but is propagated by tip layering. This consists in covering the tips of the canes with soil in late summer. By fall they are usually firmly rooted, when they can be cut free from the cane.

The young growing canes of the black raspberry should not be allowed to get much more than two and one-half feet high before being pinched back to check the upward growth and encourage the growth of laterals. The laterals when about a foot long should also be clipped back. The black raspberry, like the red, bears its fruit on canes in their second season. Therefore, it is essential to cut out the old canes after they have borne their crop of fruit. This should always be done immediately after the crop is harvested. Weak young canes should also be cut out at this time. In the spring, laterals that are over a foot in length should be cut back and not more than five or six canes to the plant should be left.

VARIETIES.

The following are the best known and most profitable varieties:

Cumberland. Undoubtedly the most valuable variety. It is prolific and vigorous. The berry is of good quality and size. Its color is a handsome glossy black. A good shipper. Somewhat more subject to anthracnose than others. Mid season.

Eureka. One of the newer varieties. Vigorous and prolific. The fruit is of a glossy black, good size and quality. Probably the best early variety.

Kansas. A very good early variety; vigorous, fruit usually of good size, quality and appearance, the color being glossy black. Some seasons the fruit is "nubby" and crumbles easily. Its season is not as long as that of the Eureka.

Gregg. For many years the best known variety. It ripens later than any of the above varieties, is vigorous and productive. The berry is large and firm, but is covered with a whitish bloom which is somewhat against its appearance.

PURPLE RASPBERRIES.

The purple raspberries are probably natural hybrids between the native red and black species. Their culture, propagation and pruning are the

same as that for the black raspberry but the fruit has the shape of the red raspberry. The color is purple to purplish red, according to the variety. The flavor is a blend of both parents and is excellent for table use, canning and preserving.

In productiveness, freedom from disease and vigor of growth, they excell either the red or black raspberry. The serious objection for market purposes is the color and softness. The color gives the impression of an over ripe red raspberry. For home use they cannot be excelled.

VARIETIES.

The following varieties are the best known:

COLUMBIAN. The best known variety. Very vigorous and productive. Hardy. Fruit is large and of high quality.

CARDINAL. The growth of this variety is more compact than that of the others. Fruit is firmer than that of the Columbian but not of as high quality. Not as productive.

HAYMAKER. Growth like that of the Columbian. Just as productive and vigorous but not as hardy.

SHAFFER. Canes not as large as Columbian. Susceptible to anthracnose. Productive, fruit large and rather acid in flavor. Has long been one of the most prominent purple raspberries but is now succeeded by the Columbian.

BLACKBERRIES.

The blackberry is undoubtedly the most profitable of the brambles. They are easily cared for, especially in localities where they do not require covering in the winter. The method of pruning the canes is like that of the black raspberry and since the plant produces suckers, the method of propagation is like that of the red raspberry and the suckers should be cut out the same as suggested with the red raspberry.

The requirements for a good location of a blackberry plantation are similar to those of the raspberry, except that more care must be taken not to select a place where the soil is too rich in nitrogen. The blackberry grows later in the fall than the raspberries and if grown on rich soil the growth will not stop soon enough to thoroughly harden the canes for winter, and winter killing may result.

Although the blackberry is quite free from disease, the same sprayings recommended for the raspberries will be found beneficial. Orange rust is frequently found in blackberry plantations. Plants affected should be cut out and burned as soon as found.

For the varieties that require covering during the winter the following method is the best: Plow a furrow toward the plants in fall to keep them from being bent over too sharply. Then bend the canes over at right angles to the row and cover with two or three inches of soil. With a fork, loosen the roots a little on the opposite side, to relieve the strain. In spring, as soon as the frost is out of the ground, the canes should be raised with a fork.

VARIETIES.

No one or two varieties of blackberries are more valuable than the others as is the case with most of the small fruits. This is undoubtedly

due to the fact that the desirable features of hardiness and size of fruit are not to be found in any one variety, but recent introductions indicate that plant breeders are nearing the ideal blackberry, one with large fruit, that will not turn red after picking and is hardy.

The following varieties are worthy of consideration:

BLOWERS. A recent introduction. A hardy, thrifty grower of spreading habit. Fruit is large, jet black color and ripens through a long season.

EARLY KING. The earliest blackberry. Fruit is good size until the end of the season when it becomes small. Hardier and a better variety than Early Harvest.

EARLY HARVEST. Compact upright grower. Does not sucker much. Moderately hardy and quite productive. Fruit of medium size. Its earliness is its most desirable feature.

ELDORADO. Productive, hardy and thrifty. Fruit holds color well and is of good size and quality. Season medium early. Probably the most valuable variety.

MESEREAU. A moderate growing, hardy variety; canes quite free from rust. Fruit is of good size and holds color well but has a slight core. Its season is short but it makes a good medium early variety.

RATHBUN. Similar to the Wilson but hardier. Grows without covering in the southern part of Michigan. Does not sucker much. Very productive of large handsome fruit of good quality. Season same as that of the Wilson.

SNYDER. A well known hardy variety. Its attractive features are hardiness and productiveness. Fruit is small but of good quality. Recommended only where better varieties will not grow.

WARD. Hardy, thrifty and productive. Fruit large and of handsome appearance. Quality good. A very good late variety.

WILSON. Once very popular, especially in southwestern part of Michigan but is being replaced by hardier varieties. It has to be given winter protection in all parts of the state. Fruit is very good size and quality. Season early.

DEWBERRIES.

The dewberry is too often overlooked by the small fruit grower. Their culture affords an excellent opportunity to lengthen the berry season and this is especially desirable for growers in the southern part of the state where the dewberry will ripen and be marketable before the blackberry and usually brings high prices.

The fruit is large, of better quality but softer than that of the blackberry. The canes are smaller and of a trailing habit. On this account, it is advisable to run wire trellises along the rows about a foot from the ground to support the canes and keep them from the ground. Pruning, cultivation, and propagation of the dewberry are the same as for the blackberry.

VARIETIES.

There are only three varieties of any value and they are as follows:

AUSTIN. Of quite recent introduction. A very thrifty grower, healthy and hardy. Productive of large berries of good quality. Fruit is a

little soft and should not be allowed to become too ripe before picking. Earlier than either Premo or Lucretia.

Lucretia. Undoubtedly the best known dewberry. Prolific, vigorous and hardy. Fruit is large and of good quality. Probably the best shipping dewberry.

Premo. One of the hardiest. Fruit is firm, of good color and quality. Should be set with Lucretia as a pollenizer.

THE MULCH METHOD OF CULTIVATION.

On a small plantation of any of the bush fruits the mulch method of cultivation might be tried with interest and possible profit where the soil is moderately rich and mulching material easily obtained. After two or three cultivations in May a heavy application of some mulching material, preferably straw, is spread about the bushes and between the rows, and allowed to remain the balance of the season. Weeds that may grow through this mulch are cut with a hoe as are the young canes if they grow too thickly.

Advocates of this practice claim that the frequent cultivations needed to conserve soil moisture destroys too many roots and that the mulching conserves the moisture and the result is more and finer fruit.

CELERY CULTURE IN MICHIGAN.

Special Bulletin No. 60.

BY C. P. HALLIGAN.

The celery industry of Michigan has advanced so rapidly during the last few years that this state stands preeminently as a celery growing region. The industry is still advancing and the next few years promise an enlarged acreage with many new districts devoted to the production of this crop. The abundance of rich muck lands and the comparatively cool, moist summers of southern Michigan combine to produce ideal conditions for the growing of this plant. Favored with these natural advantages, the growers of this state compete very successfully in the markets of less favored sections of the country, making almost an unlimited demand for Michigan celery. The leading sections of the state, where the industry has developed the most, are around Kalamazoo, Muskegon, Grand Haven, Decatur, Vriesland and Hudsonville. Other sections, however, are beginning to grow celery on the newly drained muck lands and many of these promise to become important celery growing districts. In limited quantities, celery is also grown in the truck gardens about Grand Rapids, Detroit, Bay City and many of the other cities of southern Michigan but very little of this is shipped out of the state.

DRAINAGE.

The land upon which celery is grown must be thoroughly drained. It should not be presumed that because celery grows best upon muck lands that it will thrive on wet soils. The crop must have thoroughly drained soil to produce plants of high market value. Celery becomes stunted or diseased on wet lands. Open ditches are generally relied upon to drain the fields and should be constructed in such a manner that they will drain the soil to a depth of from two to three feet. It is often advisable to further drain the land by running lines of tile between the ditches. These should be run at least two feet below the surface while a depth of three feet is more desirable. The common mistake of growers thus far has been in setting the tile too shallow and not allowing for the settling of the soil on these lands after they have been cultivated a few years. The soil settles very considerably on the muck lands and it is a very common practice of the growers who have tiled their lands to find them so shallow, after a few years, due to the settling of the soil, as to cause considerable trouble in plowing.

In the newer celery districts of the state, poor drainage is a common fault. One open ditch is not sufficient on the muck lands to drain an extensive area. Laterals should be run from the main open ditch in such a manner that they will quickly and thoroughly drain all the intervening space between the ditches even during the wettest weather. These ditches, too, should be kept clean and open and not permitted to fill

up with washed soil, weeds and other debris. Good drainage in celery culture means thorough drainage and quick drainage, draining not alone the land bordering the ditches but all the intervening land.

SOILS.

The celery of Michigan is grown entirely on the heavy reclaimed muck lands that have been previously well drained. These soils are generally very deep often extending from twenty to thirty feet before reaching the sub soil which is generally of a hard stiff clay. Three or four feet of good top soil, however, is generally considered sufficient upon which to grow good celery provided it is well drained and is a good strong muck

Fig. 2.—One of the oldest Kalamazoo celery farms. Has grown celery continuously for more than thirty years. Still very productive. Such land rents from $65.00 to $100.00 per acre per year.

soil. A shallow muck with a quicksand sub soil is not preferred and the spring muck lands, common in some sections, are also unfavorable. Black ash or elm muck lands are considered the strongest and the best for celery production.

Celery may be grown on any good garden soil that has been previously well enriched with stable manure or organic matter but for commercial growing, the muck lands are to be preferred in this state. They are fertile soils, contain much decomposing vegetable matter, and with water but a few feet from the surface of the soil, a constant supply of moisture is assured. These requisites, namely, a fertile soil well filled with organic matter and a constant supply of moisture from below are of most importance as the celery plant cannot be stunted at any time during its growth, if celery of good quality is desired. Heavy clay soils are not good celery soils as they lack the desirable physical character-

istics of a celery soil. This crop requires a soil of loose texture that does not pack hard around the plants. On clay soils, there is also apt to be considerable trouble caused by the washing of the soil over the hearts of the plants while they are small. Muck lands contain the ideal physical characteristics of a celery soil.

In Bulletin No. 99 of the Michigan Agricultural College, Doctor R. C. Kedzie states the following regarding these soils:

"PROPERTIES OF GOOD MUCK."

"A comparison of these celery soils brings out the fact that except in the amount of sand and silicates, the composition shows a close similarity.

"In a moist condition, all of these kinds of muck have a deep brown-black color, the blacker the better; they are friable, easily breaking between the fingers and are free from coarse fibrous material; they have a pleasant earthy smell, but no acid odor and are entirely free from acid reaction. When moist muck of good quality is pressed against blue litmus paper so as to wet the paper, the blue color remains and no reddening takes place. Any muck that will redden blue litmus is unfit for cultivation while this acid condition remains. * * * * All the specimens of infertile muck that have been sent here for analysis—muck that would not grow weeds even—have been of this sour class and would turn blue litmus paper red very rapidly. By draining and weathering such soils; by exposing to the action of frosts and especially by application of lime, wood ashes, even leached ashes, the acid condition can be removed and the barren soils made to produce abundant crops of a certain class."

PREPARATION OF SOIL.

In preparing new lands for celery, it is a general practice to grow corn, potatoes or some other cultivated crop the first year on the soil, to put it in as fine tilth and get it as free from weeds as possible. Summer fallowing and fall plowing are also advantageous in preparing these new lands for celery and should be practiced when it is not advisable to cultivate to crops a year before planting. If the land has been cropped for a number of years, it will be advisable to build up the soil before attempting to grow celery. Such lands are especially apt to be of a poor texture and heavy applications of stable manure should be applied to some other cultivated crop for a year or two before planting celery. If stable manure is not available, a crop of clover or other cover crop may be grown and turned under to supply the nitrogen and humus which these soils require.

When the land is grown successively each year to celery, the soil is plowed as early in the spring as possible after it is dry enough to work. Larger plows are generally used than on the uplands and the soil should be plowed deeper, ten inches being none too much. On most of the muck lands, the soil will be found too soft for discing and, therefore, the spring tooth, acme or smoothing harrow must be relied upon for preparing it. The plank drag or float is commonly used to smooth off the land, break up the clods and pulverize the soil. The land

should be alternately harrowed and dragged until it is brought down to a very fine condition. After it is thus prepared, the soil should be harrowed again after every rain or at least about once a week until planting time.

FERTILIZERS.

Celery is a rapid growing crop and requires heavy feeding to produce a continuous and healthy growth. Even on the rich muck lands, it requires heavy fertilization if continuous crops of celery are to be grown. Celery, too, requires a soil of loose texture well filled with organic matter. For these reasons, stable manure is universally considered the best fertilizer, as it fills these requirements most satisfac-

Fig. 3.—The second crop is started in hot beds about the last week in March.

torily. The amount that can be applied at a profit depends upon the intensiveness under which the crop is grown, the general condition and fertility of the land, and the cost of manure per ton laid on the land. From thirty to forty tons per acre is considered advisable each year on the Kalamazoo and Muskegon lands, where the same soil is used continuously and where two or three crops are harvested each season. In these sections, being convenient to the city, little difficulty is experienced in obtaining a sufficient supply at a reasonable price. Whether or not outlying districts where land is cheaper and the cost of manure higher, can afford to fertilize as heavily and produce as intensively, is a local problem. Where but one crop of celery is grown, about twenty-five tons per acre is sufficient on good muck lands. Many of the outlying celery districts and some of the Kalamazoo growers ob-

tain their supply of manure from the Chicago stockyards. This costs about twenty-five to thirty-five dollars a carload of thirty tons laid down in town, depending much upon its distance from Chicago. Uncertainty as to the quality of the manure and the time it will be received after it has been ordered from Chicago has tended to discourage its use among the growers.

There seems to be a strong preference in the Kalamazoo district for horse manure over the other kinds and if it contains much coarse straw, it is the practice to shake it out and apply only the fine manure. It is stacked in large flat piles about three to four feet high if obtained during the growing season and spread over the land any time in the spring before plowing. On heavy compact muck land coarse hay or straw is often turned under to make it mellow.

COMMERCIAL FERTILIZERS.

Celery cannot be grown year after year on the same land by the use of commercial fertilizers alone. We do not advise its use, therefore, as a substitute for stable manure, but we do believe that an intelligent supplementing of manure with commercial fertilizers would result in as good crops at a less cost. Muck lands are rich in nitrogen and contain, generally, a sufficient supply of phosphoric acid, but are lacking in potash. Although no definite data is available, no difference has been detected, after making careful observations, in the crops of growers where muriate of potash has been applied with twenty to twenty-five loads of manure per acre, instead of forty to fifty loads. It is probable, therefore, that the growers of celery on muck lands could greatly economize on the cost of fertilizers by reducing the amount of stable manure applied every second or third year and supplementing it with about three hundred pounds of muriate of potash.

NITRATE OF SODA.

This is a very soluble form of nitrogen and acts very quickly upon the plants. A week or two after the plants have been set in the field and have taken hold, it is a very common practice to spread a dressing of one hundred fifty to two hundred fifty pounds of nitrate of soda over the soil to stimulate the plants into producing a very early crop. The nitrate of soda is scattered along the side of the rows on top of the soil, being very careful not to come in contact with the plants, and it is then cultivated into the soil. It is preferable to do this while the foliage is dry to prevent the burning of the leaves. The effect of this fertilizer acts only for a short time, after which another application is often desirable. In producing mid-season or winter celery, nitrate of soda is not essential unless the crop becomes stunted and something is needed to stimulate the plants. As this form of nitrogen is very soluble, it is more satisfactory to apply two or three light applications at intervals of a couple of weeks than one heavy application.

SALT.

The practice of salting the celery fields is universal in the celery district about Kalamazoo, where from six hundred to eight hundred pounds

of salt are applied annually per acre. A part of this amount is broadcasted over the land in the spring after plowing and harrowed lightly into the soil a week or so before setting the first crop of plants. After this crop is harvested in early July, more salt is applied between the rows of the second crop which already are well established in the field at this time. If a third crop is grown on the field, more salt is sometimes applied, but generally, two good applications are considered sufficient for a season. It is claimed by the Kalamazoo growers that the salting makes the plants brittle, tender and of better quality.

At Muskegon, the practice of salting does not seem to be as common, although a few growers apply a small amount before planting in the spring. Its value upon the celery plants seems to be rather indefinite in the minds of most of these growers. In the other celery districts of the state, salt is not used.

SEEDING.

It is of vital importance in growing celery to be certain of obtaining first-class seed. Many of the failures are directly caused by poor seed which either fails to germinate or produces plants lacking in vitality and uniformity and very subject to diseases. Good seed must not only be true to name and germinate a large percentage of seed, but the seedlings produced should be strong and vigorous, giving the plants a good start. Most of the best seed of the self-blanching varieties is grown abroad and known in the markets as imported French seed, while California produces excellent seed of the green varieties. Celery seed therefore, should be purchased only from the most reliable seed dealers.

Celery seed loses its vitality, under ordinary conditions, very quickly, and hence fresh seed should be procured each year. Some growers, however, are successful in retaining it for a season when they secure seed of excellent quality. Although this is not to be recommended as a practice, there are times when it is often advisable to do so. To store seed successfully, it should be kept in a sealed Mason jar and placed where the temperature is moderate and uniform.

For an early crop of celery, the seed is sown about the last week in February or the first week of March. It is the aim to sow early enough to have plants of proper size ready to plant in the fields as soon as the weather conditions of the spring permit. If the seed is sown too early, the growth will be checked in the seed bed and the plants, when set in the field, will be stunted and liable to run to seed. In most of the celery sections of this state, greenhouses are erected for starting the crop. At Kalamazoo (Fig. 4), a small greenhouse covered with removable sash and heated by a small stove is generally used, while at Muskegon, a larger and more up-to-date greenhouse is built with a permanent glass roof and heated by one or more stoves. These are practical, cheap structures and economical, where celery is the only crop grown in the greenhouse. Hot beds may sometimes be used where the greenhouse is not available, but the conditions of moisture and temperature cannot be controlled as uniformly, and in many other ways, it will be found less satisfactory for starting the earliest crop.

The soil of the seed bed should consist of a rich garden soil that con-

tains an abundance of plant food and that will not pack and harden. In this state, muck soil is generally used and found very satisfactory. As the celery seed is very small and also very slow to germinate, the soil should be made very fine and smooth before sowing. It is the usual practice to sow the seed broadcast, rather than in rows, although the latter method has the advantage of permitting room between the rows to cultivate and water. The seed should be covered not over one-eighth of an inch with soil and sowed sufficiently thick to give a good stand of plants without crowding. If the seed is good, about sixty per cent of it should germinate under favorable conditions. One ounce of seed should produce at least ten thousand plants.

After sowing, the seed-bed may be rolled or carefully raked by hand. Many growers prefer to simply scatter the seed and allow the rains

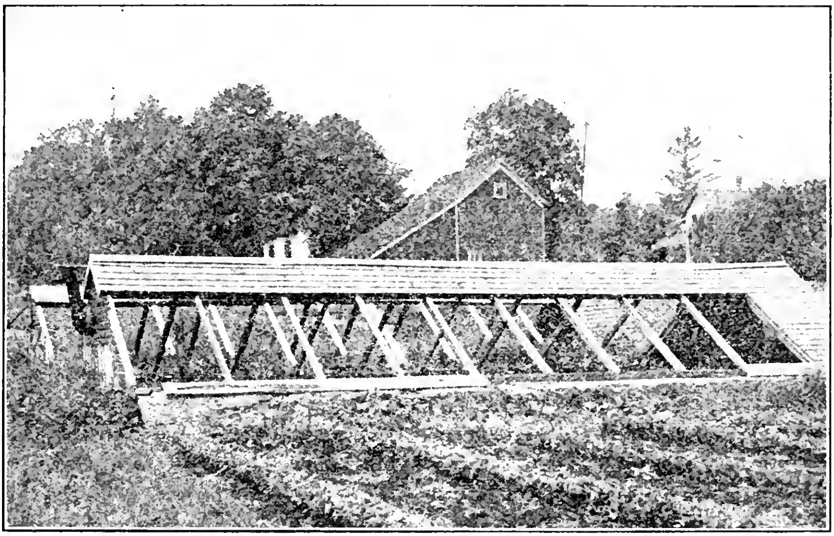


Fig. 4.—A celery greenhouse in summer at Kalamazoo. Sashes removed.

to wash it into the soil. With indoor sowing, burlap is often spread over the soil and the beds sprinkled. A large percentage of culls or small plants at harvesting time is largely due to one, or a combination of two things, namely—the use of poor seed or the crowding of the plants in the seed bed. Therefore, care should be exercised at this time, to be certain of obtaining the best seed and in not sowing the same too thick in the seed bed.

The seed of the second crop is sown about the last week in March and usually started in hotbeds. If space is available, the seed may be started in a greenhouse.

To construct a hotbed select a well drained spot exposed to the south, but protected from the north and have the bed run east and west. The standard hotbed sash is three feet wide and six feet long, although many growers prefer a longer sash, making a wider bed. Therefore the width

and length of the bed will be determined largely by the size and number of sash to be used. Whatever the size of the bed, it should be dug out to a depth of one to two feet and firmly filled with clean, fresh horse manure that has been prepared by previously stacking it for ten days or two weeks, and forking it over three or four times. This is to prevent the manure from burning after making the bed, and to induce a slow even heat to be given off by it for a long period. After firmly tramping the manure it should be covered with about four inches of good soil. A framework of two-inch plank is then constructed to hold the sash and to keep the soil from caving in around the bed. This frame should be built so that the top of the plank along the south side is about six inches lower

Fig. 5.—Seed beds. The plants are watered before lifting.

than that of the north side, thus giving each sash a slight slant toward the south (Fig. 3). The south side of the frame is also constructed at such a height that the glass along this side will be about six inches above the top of the soil in the bed. The sash may then be placed on the bed, leaving ventilation enough for the steam and gasses to pass off. A thermometer then inserted in the soil will probably show a high temperature in the bed for the first few days, but when the temperature has receded to about 85 degrees, the seed may be safely planted.

Celery that is to be harvested after the first of September is generally sown in out-door seed beds, planting the seed as early as weather conditions will permit. The soil of these seed beds should be well fertilized with fine, decomposed stable manure and fall plowed. The beds may

be slightly raised above the walks and of a width to permit convenient reaching of all plants without tramping on the beds. (Fig. 5).

The soil of the seed beds should be watered after sowing whenever the surface soil appears dry but care should be exercised to prevent over-watering. After the plants are up, they should be kept constantly growing, and watered only in the morning of bright days that the foliage may become thoroughly dried before night. If the plants in the seed bed appear too thick, they should be thinned as soon as possible by removing the weakest plants in such a way as to leave the others well spaced. The temperature of the seed-beds in the greenhouse should be kept at about 75 degrees during bright days and about ten degrees lower at night. During dark cloudy weather, it is advisable to keep the temperature somewhat lower. Ventilation should be given whenever the weather conditions permit and the plants hardened off gradually by increasing the ventilation until out of door temperatures may be favorably endured before transplanting to the field.

TRANSPLANTING.

As grown in Michigan, celery plants are not usually transplanted before setting in the field. The advantages under existing conditions, do not seem to warrant the extra labor and expense involved except when a very early crop is desired or an extra fine grade wanted for a special market, in which case it may prove a profitable practice. Transplanting induces the formation of a well branched, fibrous root system, causing a less serious check to their growth when finally planted in the field. This results in a crop a little earlier and generally more uniform. When practiced, the seedlings are transplanted into small pots, shallow boxes or into beds, placing the plants about two inches apart. The seedlings are ready for this transplanting about four weeks after seeding.

SETTING THE PLANTS.

The ideal time to set the plants is just before a shower or on a moist, cloudy day. In bright weather, it is preferable to set late in the afternoon. On large farms, it is necessary to set during all kinds of weather and at all times of the day in order to get all the plants into the ground in season. Extra care, therefore, must be exercised to gain a good stand of plants during bright, dry weather. The seed bed should be well watered a few hours before digging and the plants carefully lifted to retain a large root system.

Where only a small acreage is to be planted, they may be dug carefully with much of the soil clinging to the roots but a commercial grower can hardly afford to practice such care. The plants are usually packed in shallow pans or buckets and dropped in the field from these receptacles. The rows may be marked off with a line or marker if desired but since it is advisable to always plant in freshly stirred soil, most growers prefer to mark off but a short space at a time before planting and hence prefer the "shoe method." This operation consists in scuffing out a shallow furrow in the soil with one foot as a person walks up the row. Just before setting the plants in the row, the soil is wet down with water applied by hand from a large sprinkling can. If but one watering is given at this time, it is considered better to water before rather than after setting the plants although it is most desirable, in dry weather, to water both before and after setting.

If a boy or girl is available to drop the plants, a man can set practically double the number that he could alone and one good planter will set as fast as one can drop them. No dibble or other tool is used in making the hole to receive the plant, but the setter, straddling the row on his knees, which are generally protected with knee pads, takes the plant up with one hand while making the hole to receive it with the forefinger of the other hand. (Fig. 6). The plant is then set with its crown slightly below the top of the ground and the soil pressed firmly around the root. On clay soils, greater care must be exercised not to set the plants too deep but on muck lands and sandy soils, there is not so much danger of the soil injuring the hearts of the plants.

Fig 6.—Transplanting: The soil is first watered. The plant is then taken up with one hand, as the hole is made with the forefinger of the other.

DISTANCES.

The distance to plant celery depends much upon the variety, season, methods of blanching and intensiveness practiced. Where celery is to be blanched by boards, the rows may be set from eighteen inches to three feet apart while celery which is to be blanched with soil is commonly set from four to six feet apart. At Kalamazoo and Muskegon, where early celery is grown, the first planting is set in rows about three feet apart and the second crop is planted later between these rows. Sometimes only every alternate row is thus interplanted at first (Fig. 2) but a late crop is afterward set in the vacant places. This will leave a space of six feet for blanching the last crop with soil. When a summer crop is grown alone and the celery is to be blanched with boards, the rows are set from eighteen inches to two feet apart. (Fig. 8). In other sec-

tions, where land is less valuable and the culture less intensive, the rows are planted from three to four feet apart thus permitting horse cultivation. In outlying sections, where larger areas are handled, the cost of production will be less if planted at about this distance.

The distance the plants are set in the row is also more or less variable but three plants to a foot is the general rule in this state. Giant Pascal and other large growing varieties are usually set six inches apart while some growers even prefer a space of eight inches for this variety.

Fig. 7.—Interplanting: First crop set in rows three feet apart; second crop interplanted.

TABLE OF PLANTS REQUIRED PER ACRE.

Distance between rows.	Distance between plants.	Number of plants.	Lumber required for blanching.
18 inches	4 inches	87,000	58,000 sq. ft.
2 feet	4 inches	65,240	43,500 sq. ft.
3 feet	4 inches	43,560	29,000 sq. ft.
4 feet	4 inches	32,670	21,750 sq. ft.
5 feet	4 inches	26,136	Earth
5 feet	6 inches	17,424	Earth
6 feet	6 inches	14,510	Earth
6 feet	8 inches	10,881	Earth

One ounce of seed should produce at least 10,000 plants.

CULTIVATION.

Celery must be kept continuously growing if stalks of high quality are desired. Although an excessive feeder, demanding plenty of plant food and moisture, the plant has a very shallow root system. Therefore, constant but shallow cultivation is absolutely required to produce good crops. As soon as the plants are set in the fields, the rows should be cultivated, being especially careful not to throw any soil over the hearts of the plants. Hand hoeing may be necessary between the plants. Cultivation must be then given after every rain and as often otherwise as it is necessary to maintain a fine dust mulch over the soil. This will prevent the moisture of the soil from passing off into the air and in addition to keeping the roots well supplied with water, it will prevent the

Fig. 8.—Cultivating celery at Kalamazoo, where close planting is practiced.

roots from working deeper into the soil where the supply of air is not so plentiful and the production of plant food not so rapid. Constant cultivation induces a larger and better quality of growth by preserving the soil moisture and keeping the roots near the surface where the plant food is liberated more rapidly.

As the surface of the soil in cultivating, should not be thrown up in ridges but kept as smooth and fine as possible, a small toothed cultivator should be used in preference to the larger shovel tooth types.

About the Kalamazoo section, the crop is planted in rows too close to permit horse cultivation and the fields are worked with hand cultivators. These are especially desirable for cultivating the crop as they permit stirring the soil very close to the plant without danger of injury by deep cultivation.

BLANCHING.

The blanching of celery consists in excluding the light from the leaf stalks while the plant continues its growth which causes the destruction of the coloring matter, leaving the stalks very light colored with a mild flavor and with a more crisp and tender texture.

There are many methods that may be used to accomplish this purpose but on a commercial scale, the only ones of importance practiced in this state, are blanching by boards and by banking with soil. Formerly most of the celery was blanched by the latter method but today, the method employed depends largely upon the time of the year the crop is used. When a crop is to be blanched during the summer months, one of the self-blanching varieties is grown and the plants blanched by the use of

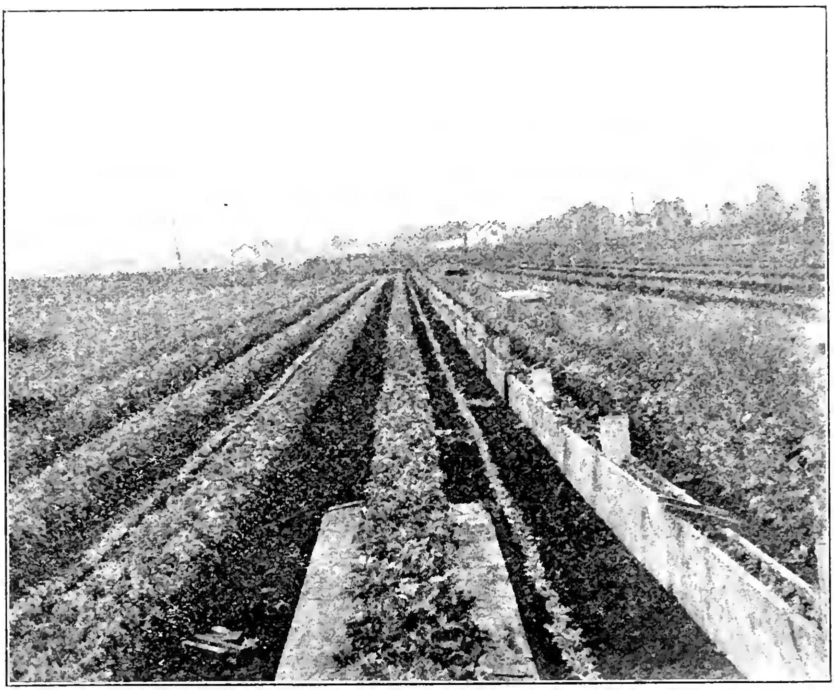


Fig. 9.—Plants ready for blanching with boards placed ready for raising.

the boards for if the soil method is used at this time, it causes the plants to rust. When celery is to be blanched during the cool weather of the fall, however, it is blanched by banking with soil which produces celery of an excellent flavor and protects the plants from light freezes. When the crop is to be stored for winter use, it will blanch in storage if the temperature is not too low and will keep better if not blanched too much in the field.

BLANCHING BY THE USE OF BOARDS.

When a crop is to be blanched by this method, sound hemlock boards one inch thick, twelve inches wide, and twelve, fourteen or sixteen feet

long are selected, although at times, boards ten inches wide are used to blanch the earliest crop when the plants are not large. If small cleats are nailed across the ends and middles of the boards, it will tend to prevent splitting and warping.

In placing the boards for blanching, they are first laid flat along both sides of the row as seen in Figure 9; then two men working together at each end of the board, raise the edge nearest the plants, catching up the outside leaves, until the board is brought into a vertical position along the row; then, holding it in place with one hand, the board on the opposite side of the row is likewise brought into position, leaving as little space between the boards as the thickness of the plants require.

Fig. 10.—Raising the boards for blanching.

(Fig. 10). Double hooks about six or eight inches long, made of heavy galvanized wire are then used to hold the upper edges of the boards together. Sometimes short pieces of laths are nailed across the tops to hold them in position but this method is not convenient for the extensive grower. After the boards are in position, a little soil should be thrown along the lower edge of the boards to close any openings that may be caused by the unevenness of the surface of the soil.

From two to three weeks will be required for blanching the summer crops, depending much upon the rate of growth and weather conditions. As soon as the crop is properly blanched, it should be harvested because when left too long, it loses in weight and flavor.

After the day's harvesting and packing is finished, the boards are carried to another patch of celery and used to blanch another crop. In this way, they are used several times in a single season.

BLANCHING BY THE USE OF SOIL.

The blanching of fall and winter celery is generally accomplished by the use of soil. This method produces crops of the highest flavor and for the extensive grower, is the most economical. The banking of celery is generally done by the use of a plow or celery "hiller" which throws the soil up in ridges against the plants. To prevent the soil from covering the hearts of the plants, the rows are first cultivated and then a small amount of soil is banked against the base of the plants by hand to straighten up the stalks and hold them together. This practice, which is called "handling," leaves the plants ready to be banked by the

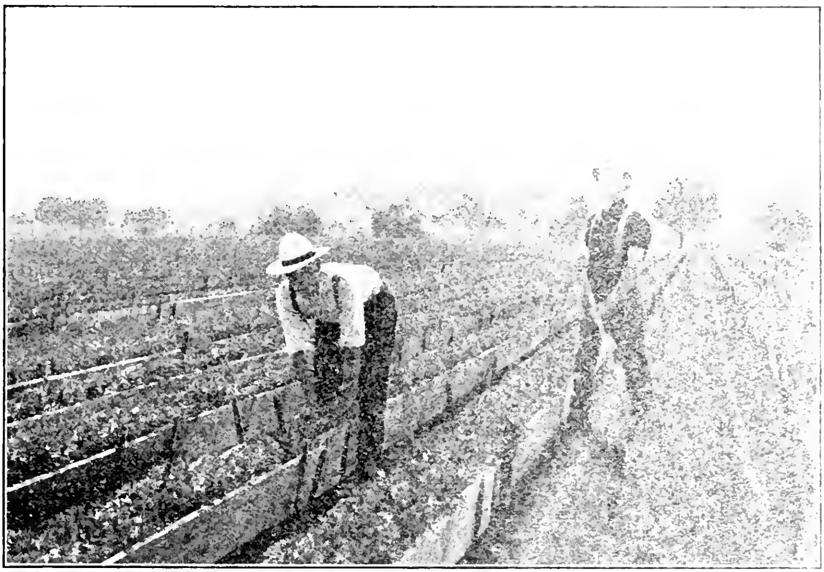


Fig. 11.—Plants almost ready for cutting. Note interplanted crop.

plow or "hiller" and as the crop continues its growth, the "hiller" is used to keep the soil thrown up about the plants.

MARKETING.

The marketing of the celery crop starts in this state about the first of July and continues more or less steadily until mid-winter. The harvesting season of the various celery districts in Michigan come at such times that one district does not enter into serious competition with another in the general markets. The Kalamazoo, Muskegon and Grand Haven districts, for example, grow early celery, starting their marketing about the first of July and continue until some time in October. Even these sections hardly compete with each other as the Grand Haven and Muskegon crops are shipped across the lake to Chicago or Milwaukee, while the Kalamazoo crop is sold largely in other cities.

being expressed to points all over the United States. During the fall, the other districts, at Decatur, Vriesland, Hudsonville and other smaller sections where the crop is grown more extensively, begin shipping and aim to dispose of most of their crop before severe freezing weather. A small portion of this crop in these districts is trenched in the field, but is generally disposed of before mid-winter, when the California product enters the market.

HARVESTING.

Celery may be harvested as soon as it attains the proper size and is

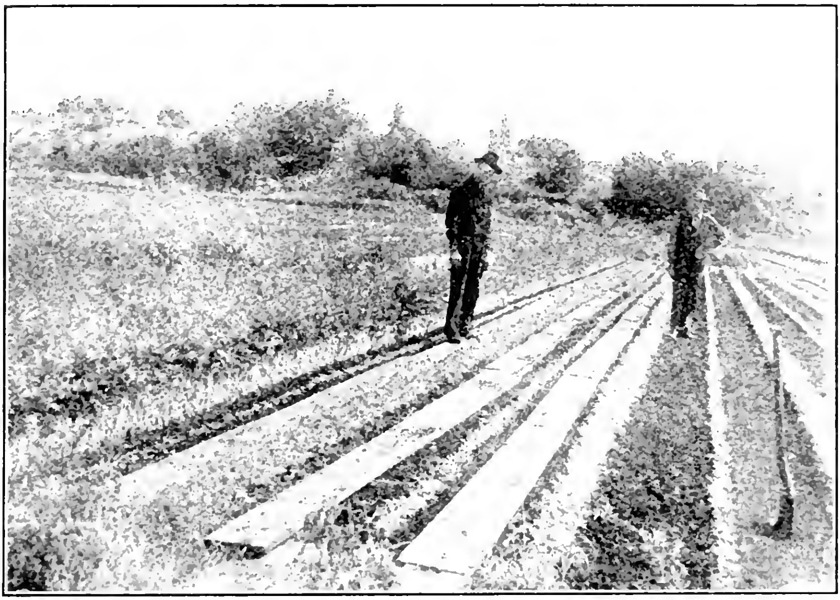


Fig. 12.—Harvesting. The boards are removed only as fast as necessary and laid between the rows to serve as walks. Note row to the left with boards removed ready for cutting.

well blanched. With the earliest crop, to gain the advantages of a high market, it is frequently cut slightly before this time and it often pays better under these circumstances than to wait for the crop to fully blanch and mature. If the plants are left too long after they have matured, they loose their crispness and flavor and are apt to become diseased.

When the crop is harvested during the summer months and is to be shipped long distances, the plants should be cut and carried to the packing shed early in the morning. In the Kalamazoo district, this work is all performed before seven o'clock in the morning. The boards used for blanching are removed only as fast as necessary and laid between the rows to serve as a walk. (Fig. 12). If the plants are left exposed to the sun and wind, they lose their firmness and are apt to wilt, hence

the boards are removed only as fast as the celery is cut. Using a stiff knife or spading shovel, the roots are cut a short distance below the surface of the soil and the plants laid in small piles along the boards. As the packing shed is generally nearby, wheelbarrows are used to gather the plants as fast as they are cut, and they are carried at once to the packing house. Where this building is more distant or the operations more extensive, wagons are used and the plants covered with canvas on the way to the packing house.

After reaching the packing house, the plants are trimmed by removing

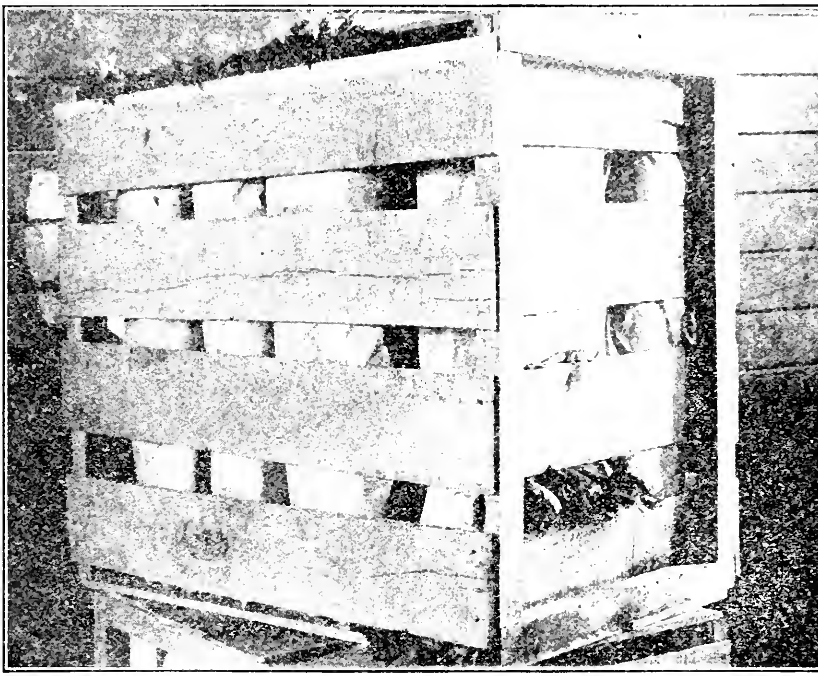


Fig. 13.—Open crates will be used more as their advantages become known.

the outer leaves and cutting the roots to a more or less conical shape with a flat point near the base of the plant. They are then thoroughly washed in clean cold water which helps to keep them in a firm, fresh condition. After being allowed to thoroughly drain for sometime, they are tied into round bunches containing twelve good sized plants. In early July, when the plants are rather small, thirteen or fourteen of them are sometimes necessary to make a good sized bunch.

Generally the only grading practiced by the growers consists in discarding the smallest plants or "culls" and bunching all the marketable sized plants together. Some growers, practice more rigid grading, selecting the largest and best plants, bunching separately and shipping these

to a special market. The smallest plants are sold locally and seldom pay to pack and ship.

In bunching celery, a board about a foot long and eight to ten inches wide is nailed along the upper edge of the packing bench, with a semi-circular piece cut out along the upper side of it large enough to hold the bases of twelve good sized plants which, when placed in it can be quickly tied into a round bunch. Extra stout white string is used, making one tie around the base of the plants and one near the tops.

Many of the more careful packers of summer shipments are now wrapping each bunch separately, with heavy brown paper using open crates as seen in Fig. 13. This tends to prevent the heating of the celery in long shipments during hot weather and will undoubtedly be used more as its advantages become appreciated. However, most of

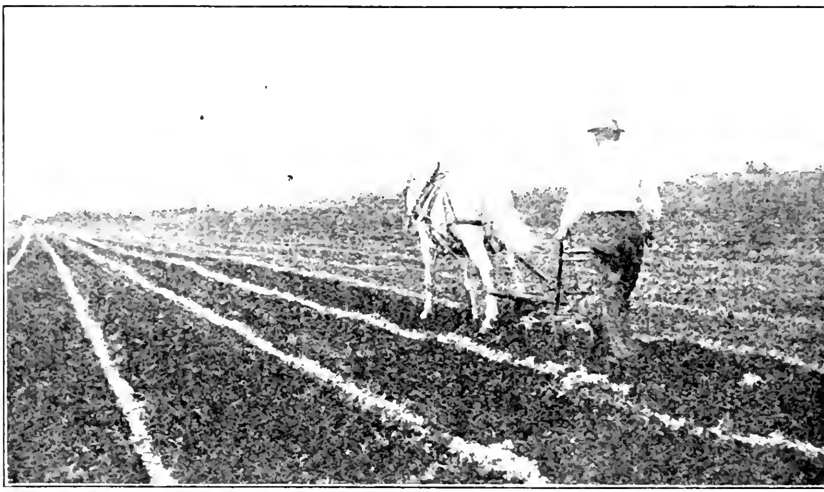


Fig 14.—Cultivating celery at Decatur. Rows four feet apart. Muck shoes are used on hind feet of horse.

shipments are made in tight crates which are lined with heavy wrapping paper. The size of the several crates used varies considerably throughout the state but the following is a list of the common sizes used at Kalamazoo:—(See Fig. 1.)

SIZES OF KALAMAZOO CELERY CRATES.

Inches	Inches
6 x 8 x 24	6 x 24 x 24
6 x 10 x 24	6 x 26 x 24
6 x 12 x 24	6 x 28 x 24
6 x 16 x 24	10 x 16 x 24
6 x 18 x 24	10 x 18 x 24
6 x 20 x 24	10 x 20 x 24
6 x 22 x 24	10 x 24 x 24
10 x 26 x 24	

In the other celery districts of the state, the crates are quite different in form and the celery frequently packed loose in the crates. The following are the sizes generally used:—

Inches	Inches
6 x 12 x 20	10 x 10 x 18
6 x 12 x 22	10 x 10 x 20
6 x 18 x 22	10 x 10 x 22

At Decatur much of the crop is shipped in the rough. When shipped in this manner some of the roots are left on the plants and only a few of the outside leaves removed. The celery is then packed in large open crates, being trimmed and bunched in the storage houses of the cities by the commission dealers before being delivered to the retailers. Shipping in this manner enables the growers to handle and ship their crop while the weather is favorable and the crop is placed in a fresh, crisp condition upon the market.

STORING.

Although most of the celery in Michigan is sold before freezing weather, about Hudsonville, Vriesland and some other sections, large quantities of it are stored for early winter. Many market gardeners about the cities of the state dealing with a special or local market also store this crop.

When the crop is to be sold in late fall it may be simply banked as high as possible with soil and the tops covered with straw, to protect the plants from light freezes. Celery that is to be stored for early winter is usually trenched. This consists of digging a trench about a foot deep in the field between the celery rows, into which the plants are closely set, so that the tops are not more than two inches above the ground. The trench may be dug by hand or by plowing out a double furrow, and the plants should be lifted from the rows while the foliage is dry, with some soil clinging to the roots. A protection of some sort must then be provided. When blanching boards are at hand they may be nailed together in a V form and placed over the trenches. If the weather then turns warm after trenching, they may be slightly raised with blocks or stones, for ventilation. As it gets colder a light furrow of soil may be turned against the base of the boards, and later, the boards covered with manure to protect the plants. If boards are not available the plants may be covered with hay or straw, until danger of severe freezing, when they may be further protected with manure.

The storing of celery in this state for late winter is generally unprofitable, and hence it will seldom pay to erect a celery storehouse for this purpose. Storage pits, vacant hotbeds or cellars are often satisfactory for storing this crop. In fact it may be stored in any place where the plants may be kept cool and moist, without danger of freezing and where thorough ventilation may be given, especially during warm weather.

DISEASES.

Celery as grown in Michigan is not as susceptible to injury of fungous diseases as in many other sections of the country. The comparatively cool, moist days of the growing season are especially favorable for the production of healthy, vigorous plants, but in seasons that are unusually warm, these diseases often become very injurious and sometimes ruin entire crops.

Damping-Off (*Rhizoctonia.*) This is the most serious disease of the celery plants while in the seed bed. During the first two weeks after the seedlings appear, it is especially apt to attack the plants. This disease causes a decay on the main stem or root just at the surface of the soil, which quickly kills the young seedling. During warm moist weather it is apt to be very injurious, spreading rapidly throughout the bed. In the greenhouse, too much heat, lack of ventilation, and watering the plants on dark cloudy days, or late in the afternoon, all tend to promote this disease. Thorough ventilation, plenty of light, judicious care in watering, in general, keeping the plants on the "dry side," tend to prevent this disease.

Early Celery Blight (*Cercospora Apii.*) A common disease of celery infecting the foliage early in the season. It first appears as well defined spots on the leaves that soon become so numerous as to cause the leaves to turn yellow and finally die. On the dead leaves the disease multiplies very rapidly and soon spreads to the other plants. It does not generally appear late in the season, but plants weakened by this disease are often afterwards attacked by the late blight. Spraying the plants with Bordeaux mixture, as recommended for the late blight will control this disease, the early spraying being especially important.

Late Celery Blight (*Septoria Petroselini.*) Of the diseases affecting celery this is generally the most common and serious one. It first appears in late summer or early fall as irregular rusty brown spots on the outside leaves, spreading under favorable conditions over the entire leaf surface and to other leaves of the plants, causing a burned appearance to the foliage in a very short time. During unusually warm, moist weather in the growing season, or after the crop is stored, this disease proves very destructive. Plants set upon poorly drained land or plants stunted or weakened by any other means are especially susceptible to it. If the plants are kept growing vigorously and well cultivated they are not as susceptible to it, and are generally able to withstand its effects. However, when the blight has become well established upon the plants it is then too late to apply effective remedial measures. The disease may be prevented also by spraying the plants with Bordeaux mixture,* using the 5-5-50 formula, or the ammoniacal carbonate of copper spray, beginning when the plants are small, spraying once before lifting them from the seed beds, and continuing the spraying every ten days or two weeks until the plants are ready to blanch by boards. The success of this work will depend largely upon the thoroughness with which the foliage of the plants is covered, as it is important that all portions of the plant be reached by this spray. All diseased plants and refuse left in the field after harvesting should be carried from the land, rather than to turn it under with its spores of this disease to cause an-

*For details of spraying send to this experiment station for bulletin on spraying.

other infection the following season. Where conditions will permit, rotation of crops will prove very desirable, devoting the land to cabbages, onions, peppermint or some other suitable crop for two or more years until the land is free of these spores.

INSECTS AFFECTING THE CELERY PLANT.*

The Celery plant is by no means immune to insect attack. It is preyed on by many of the garden pests, army-worms, cut-worms, the zebra-caterpillar, the celery-looper and by a number of other caterpillars. Besides these are several sucking insects, plant-lice, leaf-hoppers, a negro-bug and a thrips. Most conspicuous of all is the parsley-caterpillar, which works also on carrots, caroway, fennel and other plants of the same family,—a naked caterpillar nearly two inches long, green or yellow in color, with transverse black bands, and spotted with yellow. When disturbed, the larva protrudes a Y-shaped yellow horn, from which emanates a sickening odor, presumably distasteful to birds and other enemies. The adult is the common black, parsley swallow-tail butterfly, a beautiful velvet black butterfly having long swallow-tails, and marked by rows of yellow spots.

Control of these insects will depend on their feeding habits. Grasshoppers should be killed by Criddle mixture, which is poisoned and slightly salted horse-manure. Flea-beetles may be driven away or killed by arsenate of lead, while the plants are small, that being the time when most injury is done. Cut-worms like poisoned bran, made by mixing thoroughly, one pound of Paris green with fifty pounds of dry bran and then moistening it with a little molasses and water. The zebra caterpillar can be usually hand-picked profitably, as well as the parsley caterpillar. The plant-lice and negro-bugs should respond to a spraying with *strong* tobacco tea or with one of the nicotine extracts. This is true also of the thrips.

The leaf-hoppers will be driven away by such a spray, but they will return after it evaporates. For the latter, a regular practice of clean culture, and the burning of all rubbish, after cold weather has set in, will gradually get rid of them, especially if this treatment be extended over a wide area. Many noxious insects winter in rubbish, fallen leaves, along hedges, etc.

Details concerning the life-histories of some of these pests, and directions for the preparation of insecticides may be found in Bulletin 233 of this Station, being a bulletin on Insects of the Garden.

*R. H. PETTIT,
Entomologist of Experiment Station.

VARIETIES.

WHITE PLUME.

A self blanching variety that is grown almost exclusively in this state for the earliest crop. The stalks are tall and the leaves a rich dark green, turning light colored and sometimes nearly pure white when the plants are mature. It matures earlier than the Golden Self Blanching but is not considered to be quite as good in quality. Its stalks blanch a pure clean white, making it superior to all others as a table decoration.

It sells well upon the market until about the last of July when the Golden Self Blanching varieties supercede it.

GOLDEN SELF BLANCHING.

This is the most important commercial variety and is grown more than all the others in Michigan. It is about the only variety marketed after the early crop of White Plume until mid-winter when the Giant Pascal and other late sorts end the season. The plants are stocky and compact, with thick solid stalks which blanch easily to a light creamy white. The quality is excellent.

Fig. 15.—White Plume celery. A row in early July at Muskegon with boards removed ready for cutting.

GIANT PASCAL.

An extra fine green-stemmed variety producing very large bunches of broad, thick, heavy stalks. It is planted only as a late variety and requires a longer period to properly blanch. The stalks are very tender and brittle which makes it a poor shipper. Its large size and fine quality combine to make it an excellent winter sort for home or local market.

WINTER QUEEN.

A winter variety of shorter and stockier growth than the Giant Pascal, forming bunches of a size more conveniently handled. It blanches more rapidly than the Giant Pascal and being of good quality, it is becoming known as a very desirable late variety.

KALAMAZOO.

A winter market variety formerly grown quite extensively in this state. The stalks are not as broad nor do they form as large bunches as other varieties of its season. It is not planted as much as formerly.

GENERAL TREATMENT FOR APPLE ORCHARDS.

Special Bulletin No 61.

BY H. J. EUSTACE AND R. H. PETTIT.

In the winter or early spring, inspect the trees for San Jose, scurfy or oyster-shell scale. (Send twigs and strips of bark to the Experiment Station, if you cannot identify the scale yourself.)

These scale insects, especially the San Jose scale, must be destroyed promptly or they will kill the trees.

Just Before the Buds Open, if the scale be present, spray with the *strong* lime-sulphur wash. To be successful, the work must be done very thoroughly—this means that *every part* of the tree must be covered with the spray.

Just Before the Blossoms Open, or When They Are "In the Pink," a spraying must be made to prevent scab and other fungous disease and the canker-worm, bud-moth and a few other insects. For this and the sprayings that follow, use the dilute lime-sulphur or the Bordeaux mixture. To every fifty gallons, add two or three lbs. of arsenate of lead. (With lime-sulphur, this is the only poison that can be used.)

Immediately After the Blossoms Fall, and before the calyx closes, another spraying must be made just like the one before. At this time direct the spray downward from above as much as possible, and with the highest pressure available, the object being to get some of the material into the calyx cups, to poison the larva of the codling moth when it attempts to enter.

This is a very necessary spraying. If well done it usually means a crop free from worms.

About Two Weeks After the Above Spraying, make another. Use same mixture and poison as in previous spraying.

Early In August, there will be a second generation of codling-moths. Just when this will occur for your locality can be determined. (See "When the codling-moth flies" page 364.

Protect fall and winter varieties against the codling-moth and a possible late outbreak of scab. Use the usual amount of poison, but the *dilute* lime-sulphur, or the Bordeaux which can be made somewhat weaker than before.

The Lesser Apple-Worm, which works more superficially than the codling-moth, when present requires a spray of poison when standard winter varieties are from 1 to 1½ inches in diameter.

If Plant-Lice are present and if they do not leave the foliage shortly after the blossoms fall apply some contact spray, (see page 362) preferably nicotine or strong tobacco tea. If the 40% nicotine is used add ½ pint to 45 gallons of water and be sure to hit each louse.

Fire Blight has been very serious in apple trees in some parts of the state during the past few years.

For description and method of control see "Treatment for Pears" on page 349.

GENERAL TREATMENT FOR PEACHES.

Inspect for scale insects, the same as for apple, and spray with *strong* lime-sulphur wash the same as directed for apple trees.

If this spraying is made, it will also prevent the leaf-curl disease. If the lime-sulphur spraying is not required, a spraying must be made to prevent the leaf curl which is often especially serious on Elbertas. For this spraying, use Bordeaux mixture or the copper sulphate solution (2 pounds of copper sulphate dissolved in fifty gallons of water). It is very important that this spraying be made *before* the buds swell. If made after that time, it will not be successful in preventing the leaf curl.

If the fruit in your orchard is commonly affected with the rot and the scab (the small black specks usually on the upperside) and the curculio ("the insect that stings the fruit")—and most of the peach orchards in Michigan are affected with all of these—make sprayings as follows:

JUST AFTER THE BLOSSOMS DROP AND MOST OF THE "SHUCKS" HAVE FALLEN OFF, spray with poison, using 2 pounds of arsenate of lead in every 50 gallons of water.

(See under arsenate of lead page 360.)

Never use any arsenical other than arsenate of lead, on peach.

TWO WEEKS AFTER THE PREVIOUS SPRAYING, another must be made. This time use the self-boiled lime-sulphur and to every 50 gallons add 2 pounds of arsenate of lead. The *dilute* lime-sulphur has not been generally satisfactory on peaches. Even when *very dilute* some burning of the foilage has resulted.

ABOUT ONE MONTH BEFORE THE FRUIT RIPENS, spray again and the same as directed above.

In orchards where the curculio is not present or not serious, the spraying recommended "Just after the blossoms fall" can be omitted.

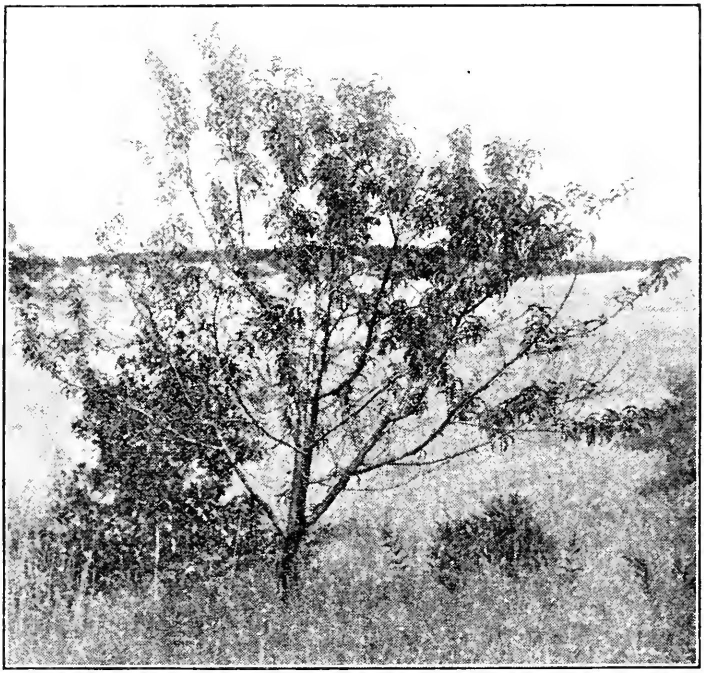
Self-boiled lime-sulphur settles rapidly, so keep well agitated and do not add the arsenate of lead until just before spraying. Use fine nozzles and give the trees a uniform coating of a mist-like spray.

PEACH TREE BORER. Dig out by hand early in spring or late in fall at points where gumming shows. Sterilize knife with carbolic acid to prevent spreading crown gall which may be present.

"PEACH YELLOWS" AND "LITTLE PEACH."

These two diseases are extremely infectious and very difficult to positively identify. Their causes are unknown and the only method of control is destruction of the tree—fruit, root and branch—as soon as discovered. It is especially important that diseased trees should not be allowed to blossom as it is believed the disease is spread by insects at that time. Both old and young trees of all varieties of peaches and probably all varieties of Japanese plums are susceptible to the two diseases. Both diseases may be present in a tree at the same time.

PEACH YELLOWS. The first symptoms in a young tree, previous to bearing, are indicated by the leaves of one or two limbs turning from a rich dark green to a "yellowish green or reddish rusty green" color; this is accompanied by a rolling of the leaves from their edges. These leaves ripen and fall earlier than normal leaves. The fruit buds are larger and more mature in appearance and in the spring will invariably bloom earlier than healthy buds. In some instances, the symptoms are not confined to one or two branches, but many of the leaves in the center of the tree turn yellowish or light green, roll slightly from their



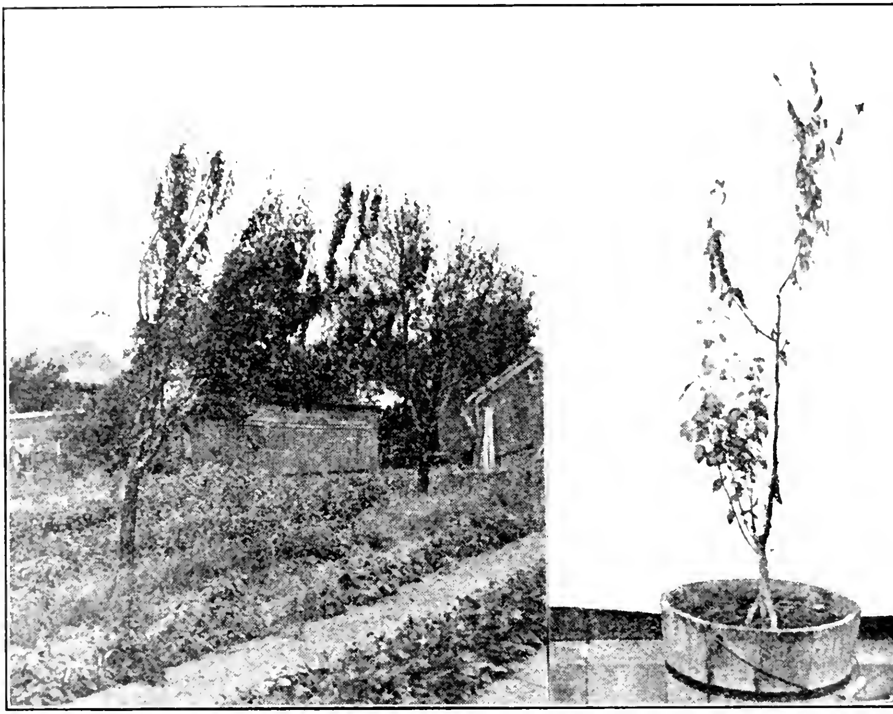
PEACH YELLOWS.
A six year old peach tree in an advanced stage of the "Yellows."

edges and droop considerably. These latter symptoms are often present in cases of "Little Peach."

Upon bearing trees, there may be any one or all of the following symptoms: the fruit may ripen prematurely—one to three weeks—upon one or two branches or over the entire tree. The fruit may have numerous red spots on the surface, the spots sometimes extending in red streaks partially or wholly through the flesh to the pit. Often the flesh, about the pit, is full of radiating streaks of red. The surface of the fruit may be smooth or considerably roughened and the flesh more or less stringy and very insipid. The leaves may be yellowish pale or reddish rusty green in color, usually rolling and drooping. In advanced stages, numerous finely branched shoots bearing many slender sickly leaves,

appear on the trunk or main limbs and sometimes in the extremities of the branches. *Finally the tree dies.*

Winter injury to the bark of the trunk or main limbs, mechanical injury by mice, rabbits, peach borers, cultivators, etc., or a serious lack of moisture or nitrogen in the soil may discolor the foliage and cause premature ripening of fruit and should not be mistaken for "Yellows."



PEAR BLIGHT.

On left: Pear blight in a bearing tree. The blight should not have been permitted to spread as far as it has in this tree. On right: Pear blight in a young tree.

LITTLE PEACH. In "Little Peach," characteristic symptoms are: the leaves of a part or the whole of the tree have a bunched appearance, and are shorter, and broader than normal leaves. They are usually yellowish-green in color with the veins appearing dilated and darker than the intervening tissue. The fruit is usually under size and ripens from a week to two weeks late. The flesh is more or less stringy, watery and very insipid while the pit is usually very small. One or all symptoms may be present and unless they can be positively attributed to some other cause, the tree should be condemned, pulled out and burned.

GENERAL TREATMENT FOR PEARS.

Inspect for scale insects and if present, spray before the buds start with *strong lime-sulphur*. The *Pear Blister Mite* (a mite that causes thickened red and brown spots on the leaves) and the *Pear Psylla* may also be partially controlled by this spraying for scale. If these pests were serious last year, make the strong lime-sulphur spraying even if not needed for the San Jose scale.

APPLY THE SAME GENERAL TREATMENT TO PEARS as is given for apples. If the *dilute* lime-sulphur is used, it should not be as strong as for apples (see dilution table on page 365.)

PEAR BLIGHT OR FIRE BLIGHT was very serious last season in many parts of the state. It is easily noticed; a branch dies back from the tip, leaves turn brown, wither, but do not drop. Is caused by a germ that works within the twig and hence spraying is not a preventative. It usually is more serious in rapidly growing trees and for this reason, many pear orchards are left in sod. Cut out the diseased twigs and branches. Make a frequent and systematic inspection of every tree and cut out every diseased twig and branch found. Cut several inches below where the wood appears to be dead. Carry the dead portion out of the orchard and bury or burn. After every cut, wipe off the wound with a cloth or sponge moistened with a 5% carbolic acid solution.

If slugs appear, spray with an arsenical, if not too near ripening of fruit to be dangerous. In case of early pears *fresh* hydrated lime may be dusted on.

GENERAL TREATMENT FOR PLUMS.

Plum trees may be infested with the San Jose or by the European fruit scale. The treatment for them is the same as recommended for scale on apples. (Page 345.)

JUST BEFORE THE BUDS SWELL, spray with the *dilute* lime sulphur (or the Bordeaux mixture) and arsenate of lead, 2½ to 3 lbs. to a barrel. This is to prevent leaf-spot, fruit rot, black knot and curculio.

Arsenate of lead is preferable to Paris green on all stone fruits, owing to tenderness of foliage in such fruits.

IMMEDIATELY AFTER THE BLOSSOMS FALL, it is very essential to make another spraying using the *dilute* lime-sulphur or Bordeaux mixture or *self-boiled* lime-sulphur, and two pounds of arsenate of lead to every 50 gallons. (For the Japanese varieties use the self-boiled lime-sulphur or dilute the Bordeaux one half.) This spraying is to prevent the leaf diseases, fruit rot and curculio. Be sure it is made *immediately* after blossoms fall. Our experiments last year showed that dilute lime-sulphur was very satisfactory on plums and it is easier to prepare and spray than Bordeaux or *self-boiled* lime-sulphur.

TEN DAYS OR TWO WEEKS LATER, it will pay to repeat the previous spraying, especially if the weather is wet or the curculio is serious. This spraying should be repeated every ten days or two weeks until there is danger of staining the fruit; stopping at least a month before picking time.

On varieties especially susceptible to rot, an application of weak copper sulphate may be made about two weeks before ripening. One pound of copper sulphate to 150-200 gallons of water. No poison need be used.

BLACK KNOT. Early in the spring a careful inspection should be made of every tree, and *all* "black knots" cut out and destroyed. Cut back several inches below the knot. Disinfecting cuts as for pear blight is not necessary. Wild cherry trees harbor the disease and if diseased

SPRAYING MONARCH PLUMS.

Tree on left: Sprayed three times with commercial lime-sulphur (properly diluted). Fruit was protected from rot and foliage remained practically perfect through the season. Photo Oct. 4, 1912.
Tree on right: Sprayed three times with Bordeaux mixture. Fruit was protected from rot and foliage remained practically perfect through the season. Photo. Oct. 4, 1912. On an adjoining tree not sprayed, the crop of fruit was entirely destroyed by rot and all of the foliage fell off by August.

ones are near plum or cherry orchards, they should be destroyed, if possible.

GENERAL TREATMENT FOR CHERRIES.

Cherry trees may be infested with San Jose scale. If found, the treatment is the same as that recommended for the apple.

JUST BEFORE THE BLOSSOMS OPEN, spray with dilute lime-sulphur, or Bordeaux mixture. This is to prevent the rot and leaf spot troubles.

Especially valuable on the English Morellos for the latter. Our experiments the last two seasons indicate that the dilute lime-sulphur is just as satisfactory as the Bordeaux for cherries and either is better than the self-boiled lime-sulphur.

Just After the Blossoms Fall, make a spraying like the above with the addition of 2 pounds of arsenate of lead to every 50 gallons of spray solution. This spraying is directed against the rot and leaf spot, curculio and slug.

Ten Days or Two Weeks Later, it may be necessary to make another spraying like the previous one for the rot and leaf spot. The need for this spraying will depend upon the susceptibility of the variety to the rot and to the weather conditions of the season.

Large Black Lice may appear on the leaves at any time. A spraying of tobacco water (see page 363) will destroy them if applied before the leaves curl too tightly.

SPRAYING ENGLISH MORELLO CHERRIES.

On left: Sprayed three times with commercial lime-sulphur (properly diluted). Fruit was protected and foliage remained practically perfect through the season. Photo. Oct. 4, 1912. There was no perceptible difference when the Bordeaux mixture was used. On right: Tree not sprayed. The fruit was of no value and the foliage was entirely lost by mid-summer. The photograph was taken Oct. 4, 1912.

Slugs sometimes appear after the fruit is harvested, a spraying of arsenate of lead (2 or 3 pounds in 50 gallons of water) will destroy them.

GENERAL TREATMENT FOR GRAPES.

Grape vines are not often subject to attacks by scale insects so there is seldom need for a spraying with *strong* lime-sulphur before growth starts.

Do not use the *dilute* lime-sulphur at any time for grape spraying. It stunts or checks the growth of the berries. Use the Bordeaux mixture.

DOWNY MILDEW commonly called "Red Grape" was very destructive last season and caused large financial losses to growers who did not spray.

BLACK ROT has been a serious disease in recent seasons. Growers cannot afford to risk the loss it may cause by neglecting to spray.

These diseases and others will be prevented very largely by spraying as follows:

WHEN THE SHOOTS ARE ABOUT 8 TO 10 INCHES LONG, spray with Bordeaux mixture for black rot and downy mildew.

JUST BEFORE BLOOMING spray again with Bordeaux mixture for black rot and downy mildew and to every 50 gallons of Bordeaux, add 2 or 3 pounds of arsenate of lead to poison the grape-berry moth, and the rose-chafer. If this latter is serious use stronger poison even up to 5 lbs. to 50 gallons. A pint of the cheapest molasses added may help.

JUST AS THE BLOSSOMS ARE FALLING, make another spraying like the above.

ABOUT 10 DAYS OR TWO WEEKS LATER, it may be necessary to make another spraying like the two previous, but this will depend upon the weather conditions and the amount of rot and mildew prevalent. If later sprayings are thought to be necessary, some material should be used that will not stain the fruit such as weak copper sulphate solution.

There are several grape insects that are found only in occasional vineyards and then not every year. The grower should keep a sharp watch of his vines for them and if found, take prompt measures to destroy them. (If not familiar with their appearance send specimens to The Entomologist, East Lansing, Michigan.)

Those most likely to be found are the following:

FLEA-BEETLES may appear at any time but are most likely to come as the buds open in early spring. Spray with Bordeaux mixture and a strong poison, 3 or 4 pounds of arsenate of lead to every fifty gallons of the Bordeaux; if early in spring. Later use less poison.

In vineyards where the grape-berry moth is serious, spray with Bordeaux and an arsenical poison during the middle of July, before the 20th.

For leaf-hoppers, sometimes incorrectly called "Thrip," spray with nicotine or with kerosene-emulsion while the insects are young, and before they can fly. Later in the fall, clean up all rubbish and burn after cold weather sets in.

For climbing cut-worms, use cotton bands or bands of sticky mixture. On tender growth these can be put on strips of paper.

GENERAL TREATMENT FOR CURRANTS AND GOOSEBERRIES.

San Jose and European fruit scale are often found upon these bushes. Inspect carefully for them. If found, spray before growth starts with *strong* lime-sulphur.

JUST AS THE LEAVES ARE EXPANDING, spray with *dilute* lime-sulphur or Bordeaux and two pounds of arsenate of lead to every fifty gallons.

REPEAT this spraying when the fruit is about one-fourth grown.

If worms trouble after this, use pyrethrum or hellebore.

Leaf bugs or aphids may appear. When they do, spray with nicotine or strong tobacco water while the bugs are red and wingless and before the leaves have become curled.

Gooseberry Mildew is a fungous disease that is especially troublesome on the English varieties as Industry, Columbus and Chautauqua. Spray with dilute lime-sulphur. Begin when the buds start and repeat every 10 days to two weeks until near picking time.

When Pruning, if a cane is cut that shows discolored pith, it may indicate the cane borer. Cut back to sound pith. Burn trimmings.

Wilted Foliage at any time indicates the cane borer. Cut out and burn.

GENERAL TREATMENT FOR RASPBERRIES, BLACKBERRIES AND DEWBERRIES.

Cut out the Fruit Bearing canes after the last picking has been made. This will lessen insect and disease troubles that may be harbored on the old canes and allow more room for the growth of the new canes.

Orange Rust may appear in May or June. It is easily identified by the bright orange color on the under side of the leaves. There is no method of preventing this trouble. As soon as it is found, the bush should be dug out and burned. If allowed to remain the disease will spread and destroy many plants.

Anthracnose, identified by the grayish spots on the canes (also on leaves, but not conspicuous), is common in many berry fields. It does not yield to spraying unless very frequently done with Bordeaux mixture and this may not be profitable. If desirable, make the first spraying when the new canes are 6 to 8 inches high and repeat every two weeks during the growing season.

Cutting out and burning the old canes immediately after fruiting will be of some benefit. In starting a new field, make a special effort to secure healthy plants.

"Worms" or "Slugs" might appear at any time. Spray with an arsenical if early in season, but if near picking time, use hellebore or pyrethrum.

Cut out and burn gouty galls, tree cricket eggs or borers in stems.

GENERAL TREATMENT FOR STRAWBERRIES.

Examine the young plants before setting them. Pick off all discolored or diseased leaves. If root lice are suspected, dip the roots in strong tobacco water.

After the growth starts, spray with Bordeaux and a poison to prevent the leaf spot and to destroy the leaf-roller insect that may be present.

For fruiting plantations, spray with Bordeaux before blossoming and

repeat ten days to two weeks later. After fruiting if the bed is to be fruited again, mow and burn over quickly (as on a day when there is a wind, to avoid burning the crowns of the plants), If leaf rollers have been present, spray with poison after the growth has started again, but before the leaves curl.

For strawberry root lice, see Michigan Bulletin No. 244, page 88.

GENERAL TREATMENT FOR POTATOES.

For the Potato Scab. Soak the uncut tubers for two hours in 30 gallons of water and one pint of formalin (can be secured of any druggist). This solution can be used several times. Do not put treated tubers back into crates or bags that held scabby potatoes. Make the treatment only a few days before planting if possible. Do not plant upon land that has recently grown crops of scabby potatoes or beets.

For the Blight and "Bugs." Begin spraying with Bordeaux mixture and poison when the "bugs" first appear, or when the plants are about 8 inches high, and repeat about every 2 weeks as long as the plants are growing. Spray often in warm, muggy weather; fewer sprayings are necessary in dry weather.

Use Bordeaux mixture (6 pounds copper sulphate and 4 or 5 pounds of lime to 50 gallons of water, and put in the poison, about ½ pound of Paris green or 2 pounds of arsenate of lead, or 1 quart of the stock solution of Kedzie mixture).

Dilute lime-sulphur is not as good as the Bordeaux mixture for potatoes.

Wart Disease of the Potato. This disease also is known as Black Scab, Canker or Cauliflower Disease. It attacks the tubers mainly. In a severe attack, big, dark warty excrescences sometime as large as the tuber itself appear at the sides or ends. In advanced stages of the disease, the tubers are wholly covered by this growth and lose all resemblance to potatoes. In the final stages, the tubers turn to brownish black soft masses, giving off a very unpleasant odor. In very mild attacks, the tubers appear normal, but the eyes are found to have turned gray, then brown and finally black.

This disease is not known to be present in Michigan, but is likely to be found at any time. No remedy is known. When once introduced into a field, the whole crop should be burned and no tuber from the field used for seed purposes. The field itself should not be used for potatoes for at least six or seven years and the disease should be reported together with specimens at the first outbreak or suspicion of outbreak to the Department of Botany, Michigan Agricultural College.

Send specimens in a tight mailing-case.

PREPARATION OF SPRAY MIXTURES.

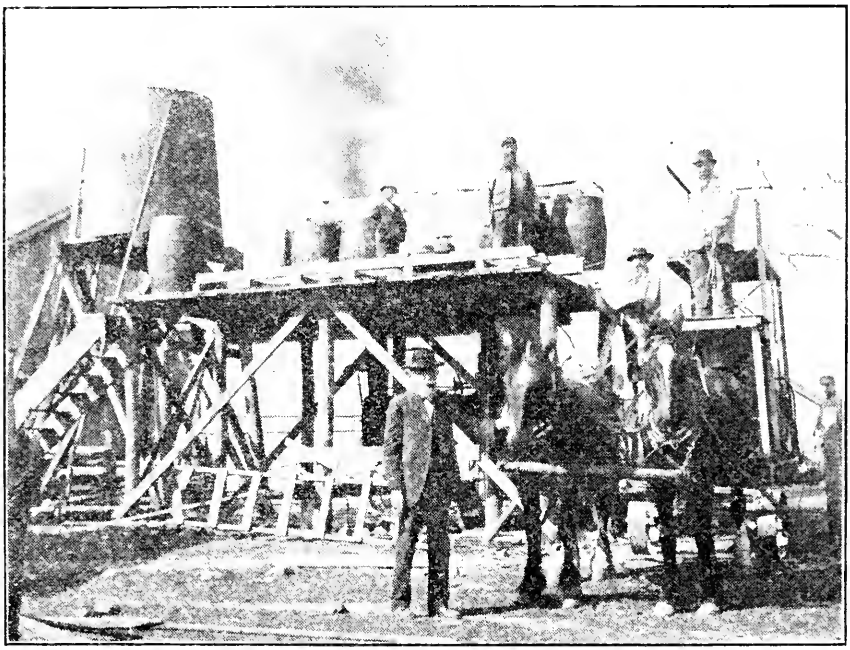
STRONG LIME-SULPHUR.

Strong lime-sulphur to be used on dormant trees or bushes for scale insects, can be prepared in three ways:

By the old formula,

By reducing with water "the home-made" concentrated wash.

By reducing with water the "commercial" concentrated wash.



A HOME COOKING PLANT.

An outfit for the cooking of the lime-sulphur at home. Water supply tank on the left. The cooking is done in barrels into which are extended perforated steam pipes. The steam is supplied by traction boiler.

The "Old formula" has been used for many years with good results and is very satisfactory. The formula is as follows:

Lump lime	20 pounds
Sulphur (flour)	15 pounds
Water (hot) to make	50 gallons

The lime is slaked with a small amount of water (hot if lime is sluggish) and the sulphur is added, fifteen or twenty gallons of water are then added, and the mixture boiled. (It should take three-quarters

of an hour, or an hour of good boiling with frequent stirring.) When done the liquid should be amber colored and fairly clear. Strain, dilute with water (hot is preferable) to make (up to) 50 gallons, and apply warm, through a coarse nozzle.

If small quantities are required, use an iron kettle to boil it in. If larger quantities are to be used, live steam is preferable for boiling purposes, either in a tank or in barrels.

Applied just before the buds swell, it coats the branches in such a way as partially to hinder from settling down, such pests as the oyster-shell, scurfy scale, some aphids and other insects.

HOME-MADE CONCENTRATED LIME-SULPHUR WASH.

Growers, having cooking plants, can make the lime-sulphur wash in a "concentrated" solution. This may be an economy of time, as large quantities can be made early in the season and stored until needed.

It is difficult to make this wash of uniform strength. For this reason, every batch that is made must be tested with a hydrometer and diluted accordingly.

The difficulty of getting a solution of uniform strength, apparently depends on the lime, which varies in composition and strength. Lime that contains more than five per cent of magnesium oxide and less than 90 per cent of calcium oxide does not combine in the cooking with the sulphur in a way to make a good mixture. Special "spraying lime" is now on the market.

There are several ways of combining the lime and sulphur, but always there are two parts, by weight, of sulphur to one of stone lime. The following three formulas are in common use:

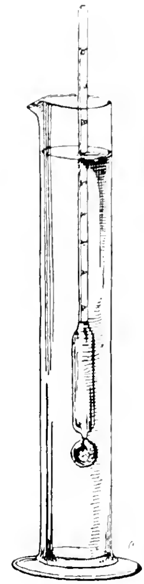
Stone lime	75 lbs.	or	60 lbs.	or	40 lbs.
Sulphur	150 lbs.		120 lbs.		80 lbs.
Water	50 gal.		50 gal.		50 gal.

The lime is slaked to a thin paste and the sulphur is added. Boil for one hour and stir frequently. Water enough should be added so that there will be fifty gallons at the end of boiling.

After it is cooked, if not to be used at once, it should be strained into a barrel which should be air tight, as exposure to the air causes the sulphur compounds to lose their value for spraying purposes. Each lot that is cooked should be tested with a hydrometer when cooled and diluted, according to the dilution table on page 365, when applied:

COMMERCIAL CONCENTRATED LIME-SULPHUR WASH.

There are several brands of the "commercial" concentrated lime-sulphur solution now upon the market. The use of these instead of the home cooked kinds is becoming more and more common every year, especially by fruit growers who do not care to take the time or trouble to cook the material for themselves or if they do not have good facilities for doing so. They are now reasonable in price,—of fairly uniform strength, and do add to the ease of getting ready to spray as all that is necessary is to dilute with the required quantity of water.



TESTING AND DILUTING CONCENTRATED LIME-SULPHUR.

Every "batch" of the home made concentrated lime-sulphur wash will have to be tested when cooled to determine its strength and it will be well to test the "commercial" brands. This testing is done with a Baume hydrometer. It is a simple instrument used to determine the weight and density of liquids. It is made of glass, is about a foot long, and has a graduated scale on the side.

It is absolutely necessary that the hydrometer be kept *perfectly clean.* If the solution is allowed to dry on it an accurate test cannot be made.

It can be purchased from dealers in druggists supplies or from Bausch and Lomb Optical Company, Rochester, N. Y., Whitall Tatum Company, Philadelphia, Pa., or Taylor Instrument Companies, Rochester, N. Y.

(See page 365 for the rates of dilutions.)

AMOUNT OF SULPHUR IN SOLUTION.

The relation between the "Baume Test" and the sulphur in solution in the commercial or home made concentrated lime-sulphur wash can be determined from the following table.

Density, degrees. Baume.	Total sulfur. %	Pounds of sulfur in one gallon of solution. lbs.
33	26.0	2.7
32	25.0	2.6
31	24.0	2.5
30	23.0	2.4
29	22.0	2.3
28	21.0	2.2
27	20.0	2.1
26	19.5	2.0
25	19.0	1.9
24	18.5	1.8
23	18.0	1.8
22	17.75	1.7
21	17.0	1.6
20	16.75	1.6
19	16.25	1.5
18	16 0	1.5
17	15.5	1.4

Cir. No. 10 Mich. Exp. Station.

DILUTE LIME-SULPHUR SOLUTION.

For spraying on the foliage of apples, pears, European plums and cherries but not on peaches or Japanese plums, grapes or potatoes.

This solution can be prepared for use in several ways.

First. The "commercial" concentrated lime sulphur solution can be diluted to the proper strength.

Second. The "home made" concentrated lime-sulphur can be diluted to the proper strength.

Third. The solution can be made at any time and in any quantity as follows: Boil in a few gallons of water for one hour, *twice* as many pounds of sulphur as of lime, strain and dilute with water so there will be 8 pounds of sulphur to every 100 gallons.

Example: To make 100 gallons of spray solution, boil 8 pounds of sulphur and 4 pounds of lime as directed.

SELF-BOILED LIME SULPHUR MIXTURE.

This is a mixture of lime, sulphur and water and not like any of the other lime-sulphur sprays. It does not (when properly made) injure tender foliage and is very valuable for spraying peaches and Japanese plums.

The formula is:

Lump lime	8 pounds.
Sulphur	8 pounds.
Water	50 gallons.

The mixture can be prepared better by using thirty-two pounds of lime, thirty-two pounds of sulphur, and eight or ten gallons of water, and then diluting to 200 gallons.

Place the lime in a barrel and add enough water to almost cover it, as soon as the slaking begins, add the sulphur, which should be run through a sieve to break up the lumps.

Stir constantly and add enough water to make a thick paste and then, gradually, a thin paste. As soon as the lime is well slaked, cold water should be added to cool the mixture and prevent further cooking. It is then ready to be strained into the spray tank, diluted up to the full formula, and used.

Care must be taken not to allow the boiling to proceed too far, if the mixture remains hot for fifteen or twenty minutes after the slaking is completed, some sulphur will go into solution and injury to the foliage may result.

The time of adding the cold water to stop the boiling depends upon the lime. With a sluggish lime all the heat in it may be needed, while with limes that become intensely hot, care must be taken not to allow the boiling to proceed too far.

SOLUBLE SULPHUR POWDER.

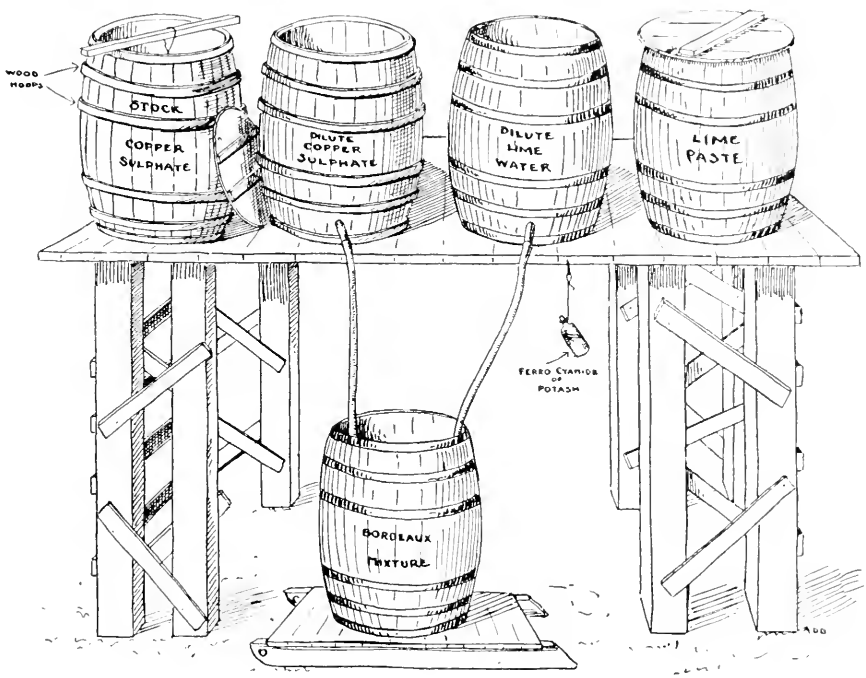
There has appeared on the market a form of sulphur compound that can be dissolved in water, and is recommended as a substitute for lime-sulphur. It has been tested in a limited way by this Experi-

ment Station; one apple tree, badly infested with the San Jose scale was sprayed in March 1912. Frequent examinations indicated that the scale was destroyed. More extensive experiments are in progress.

BORDEAUX MIXTURE.

Bordeaux mixture is made of copper sulphate, lime and water.

These three substances are combined in various proportions, depending upon the kind of plant to be treated. For apples, pears, cherries and plums (except Japanese varieties) the preparation is usually four pounds of copper sulphate, with about the same amount of lime, to fifty gallons of water. Poison is added as needed. The copper sulphate will



readily dissolve in two gallons of hot water, to which should be added enough water to make twenty-five gallons or one-half barrel. Do not use an iron or tin vessel to dissolve this in, as the copper sulphate will destroy it, and besides the iron will spoil the Bordeaux. A wooden pail is good. Slake the lime into a thin paste and add water to make twenty-five gallons. Pour, or let these run together into a third barrel, and the Bordeaux is made. When it is emptied into the spray barrel or tank, it should be strained through a brass wire strainer to catch any of the coarse particles.

Whenever it is necessary to use a quantity of the mixture, it is desirable to have the lime and the copper sulphate in "stock solutions." A quantity of lime is slaked to a paste and held so by being covered with water. The copper sulphate, say fifty pounds, is placed in a clean

gunny sack and suspended in a barrel (one with wood hoops is much to be preferred) containing twenty-five gallons of water. This will dissolve in about a day. One gallon of this "stock solution"* is equal to two pounds of copper sulphate.

A good quick way to combine these three substances is as follows: Put the amount of the "stock solution" of copper sulphate required in a barrel, and add enough water to make 25 gallons, or one-half barrel. Put about 7 pounds of the lime paste in a barrel and add 25 gallons of water, making a thin whitewash. Pour, or let these two run together into a third barrel, or directly into the spray barrel or tank, being sure to strain. When partly run in, test with ferro-cyanide of potash† to make sure enough lime has been used. If Paris green, arsenate of lead, or any other poison is to be used, make it into a thin paste with a little water and add it to the Bordeaux mixture, which is now ready to be used.

COPPER SULPHATE SOLUTION

Is copper-sulphate dissolved in water. It is used by some growers to spray peach trees to prevent the leaf curl where a spraying for scale insects is not required. Two pounds of copper sulphate to 50 gallons of water is strong enough for this purpose.

POISONS USED IN SPRAYING.

For Insects That Chew.

ARSENATE OF LEAD.

This poison is used very extensively. It can be secured for reasonable price, is ready to use at any time, does not easily injure the foliage and is the only poison that can be safely used in the lime-sulphur sprays.

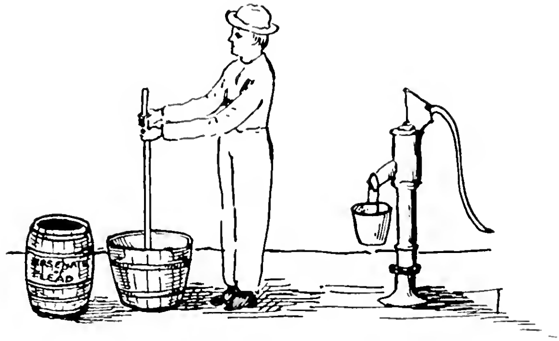
Injury to tender foliage like the peach has occasionally occurred by spraying with arsenate of lead and water when the foliage was moist from dew or rain. If necessary to spray tender foliage (peaches or Japanese plums) at such a time it would be well to add 3 to 5 pounds of slaked lime to every 50 gallons of the spraying material.

Arsenate of lead is usually sold in kegs or "kits" or small barrels in the form of a paste. Some companies have it in a powdered form. This form usually costs twice as much or more per pound as the paste form and since it does not contain much water only one-half the amount in weight should be used as is recommended for the paste form.

A simple, easy way to work the thick pasty arsenate of lead into a thin, smooth paste (as it should be before using either alone or in something) is to put the amount required in a keg; add water and churn with a dasher. This is much quicker than to use a paddle.

* Always stir this "stock solution" before dipping any out, in order that what is used may be full strength.

† This chemical can be secured of any druggist. Ten cents worth dissolved in a pint of water will be enough for a season. Drop a very little in the Bordeaux, if a reddish brown color appears more lime must be added. If there is no discoloration, there is enough lime. Ferro-cyanide of potash is extremely poisonous, so observe great care in its use.



PARIS GREEN AND LIME.

Always use lime with Paris green, it makes the poison stick better, besides greatly reducing the danger of burning the foliage.

For spraying from a barrel, the writer has found the following method very useful: Place from one-quarter to one-half pound of good lump lime, or unslaked lime, in each of three or four tin pails which will hold about three quarts or less. Old cans or crocks will answer just as well. Add enough hot water to slake it into a thin cream or paste. Now add to each lot, one-quarter pound of Paris green, previously weighed out, and placed in paper bags, stir while the lime is hot and allow to stand for some time. Now measure out about forty-four gallons of water in your spraying barrel, and make a mark that will show how high it comes in the barrel, add the contents of one tin pail (viz., one-quarter of a pound of Paris green and one-half pound of quick-lime slaked) into the forty-four gallons of water in the barrel. Stir well and spray. The pails or crocks can be used one at a time and refilled occasionally so that the stock is always on hand ready for use.

ARSENITE OF SODA—KEDZIE FORMULA.

This form of poison was originated at this Station by the late Dr. R. C. Kedzie.

This is a cheap, effective poison that can be prepared at home. It is used by many of the grape growers of Michigan in combination with the Bordeaux mixture. It cannot be used in the lime-sulphur sprays. If used alone—as is sometimes done for potato bugs—slaked lime must be added or the foliage will be burned.

The formula is:

White arsenic	2 pounds
Sal Soda (commonly called washing soda)	8 pounds
Water	2 gallons

Boil these materials in any iron pot or kettle *not used for other purposes* for about 15 minutes or until the arsenic dissolves, leaving only a small muddy sediment. Put this solution into a jug or other vessel that can be closed tightly and label "Poison."

One quart of this solution is equal to ½ pound of Paris green. For most spraying one quart in 50 gallons of water (with some lime) or Bordeaux mixture will be sufficient.

CONTACT INSECTICIDES, FOR INSECTS THAT SUCK.

KEROSENE EMULSION.

Place two gallons of ordinary kerosene in a warm place, either in a warm room or in the sun, and allow to become as warm as possible without danger from fire. Boil one pound of laundry soap or whale oil soap in a gallon of soft water until completely dissolved. Remove the soap solution from the fire, and while still boiling hot, add the kerosene and agitate vigorously for ten minutes, or until the oil is emulsified, with a spraying pump by forcing the liquid back into the vessel from which it was pumped. When the liquid is perfectly emulsified it will appear creamy in color and will flow evenly down the side of the vessel when allowed to do so. Care should be taken to completely emulsify the oil and this is accomplished much more easily when the mixture is hot.

This strong emulsion may now be readily diluted with water and used, or it may be stored away for future use. When cold it becomes like sour milk in appearance and should be dissolved in three or four times its bulk of hot water before diluting with cold water. If the water is at all hard, "break" it by adding a little sal soda before putting in the soap.

Small amounts of this emulsion may be made by using the ingredients in small quantities, but in the same relative proportion.. It is used at the rate of eight or ten parts of water to one part of emulsion.

HELLEBORE.

White hellebore is the powdered root of a plant. It kills both by contact and as an internal poison. It may be applied either dry or in the form of a liquid. When used dry it should be mixed with three or four times its weight of flour or of plaster and then dusted on the insects. Applied wet, one pound should be mixed with twenty-five gallons of water and this liquid applied as a spray.

INSECT POWDER, BUHACH, PYRETHRUM.

This valuable remedy has one drawback, its cost. It is too expensive for use on a large scale. It kills insects through their breathing pores, but is harmless to man and beast. It will kill many of the insects of the garden if dusted on or applied as a spray at the rate of one ounce to two gallons of water.

Use the powder when it is undesirable to use poison, but never buy any unless it comes in tightly sealed packages. It loses its strength on short exposure to the air. An hour will suffice to weaken it. It must be applied from time to time, as it quickly loses its strength.

TOBACCO.

Tobacco in the form of dust may be obtained of the large manufacturers for a few cents a pound.

It is useful in destroying root-lice, especially woolly-aphis, in young trees, and in keeping insects from garden truck. For root-aphis, incorporate four to six handfuls of tobacco dust into the soil about the roots and induce a thrifty, healthy growth by using liberal quantities of nitrate of soda or barnyard manure early in the spring.

A *strong* infusion or tea made of waste will kill plant lice if sprayed when they first appear.

Nicotine is to be had now in concentrated form. It is more often sold about 40 per cent strong. This may be diluted many hundreds of times before applying. As there is a diversity of grades and brands to be had, it will be well to use the strength recommended by the makers.

HYDRATED LIME.

Finely slaked lime is often useful because of its slight caustic properties. Against such larvae of saw-flies and beetles as are sticky, for instance, those of the cherry-slug and asparagus-beetle, it may be used as a substitute for poison, if the latter, for some reason is undesirable.

Stone lime may be slaked with a small amount of hot water, using just enough to turn it to a dry powder. Such slaked lime is as fine as flour and very soft to the touch, having very little grit. Use a metal pail or kettle to slake in, as the heat may set fire to wood. Do not use too much water, and where possible, use freshly burned lime.

Hydrated lime may be used in making Bordeaux mixture, but it is not as reliable as good, fresh, lump lime. It is less adhesive, not as strong (so more should be used) and more expensive. The one advantage is that it is a little easier to use.

Ground lime for making Bordeaux mixture acts exactly like lump lime, if fresh, but this is difficult to determine as it is already in a powder.

CAUTIONS.

Do not spray while plants are in bloom. It is prohibited by law, except when canker-worm is present, and may destroy bees and other beneficial insects.

Do not dissolve copper sulphate in an iron or tin vessel. It will ruin the vessel and spoil the spraying solution.

For all spraying solutions containing copper sulphate, the pump must be brass or porcelain lined.

Wash out pump and entire outfit each time after using.

Use arsenate of lead on stone fruits in preference to other forms of arsenical poisons. It is less liable to burn the foliage.

Do not spray fruits or plants with poison within a month or more of the time when they are to be picked.

Keep all "stock solutions" covered to prevent evaporation.

Do not spend money for freak "cure-alls," such as powders to be put into a hole bored in the trunk or limbs of trees or liquids to be diluted and poured on the ground beneath the trees. They may do considerable harm.

WHEN THE CODLING-MOTH FLIES.

While the first week in August is a good average time for applying an arsenical spray for the second generation of the codling-moth in Michigan, it is well to remember that seasons vary, and that the time set aims merely at an average. To determine exactly each year just when to get the highest efficiency out of a spray, for a particular locality, requires only a few hours of work, providing one can find some neglected apple trees near at hand.

First of all scrape off all loose bark-flakes from the trunk and limbs of several trees, thus destroying all the natural places for the hiding away of the cocoons. The scraping is most easily done while the bark is soft after a prolonged rain.

Next, make some bands of burlap six or eight inches broad and three or four layers thick; place one around the trunk of each prepared tree and fasten with a headless wire nail driven into the tree so that the band can easily be removed. Do this in June so that the cloth may become weathered before the time for spinning. The larvae in searching for a good place to spin cocoons will find the bands, in the absence of other protection, and spin cocoons there.

Occasionally examinations during July will reveal these cocoons which should be carefully removed by cutting out a small bit of the cloth to which each is fastened.

Place all these bits of cloth with the cocoons attached in a cage made of a lantern globe or some other glass cylinder open at top and bottom, and then tie a bit of mosquito netting over the top to confine the insects when they come out of the cocoons. If the lantern globe is set on a little soil in a flower pot and the soil is kept just slightly moist, the chances of getting the moths out are increased.

Now put the cage thus prepared in a shady place where the sun cannot strike it to sweat it, and where the rain cannot penetrate. Outside of protection from rain and sun the conditions should be as near those of the outside as possible. Keep the soil in the pot just moist and look for the moths often during late July for they will hide down under the layers of burlap and may be overlooked. When you see them in the cage, then you will know that they are laying eggs in the orchard and the time to spray is just before the young hatch and go into the fruit, which is about a week or ten days later, not afterward. Of course, they do not come out all together, but string along over quite a period.

TABLE OF DILUTIONS FOR CONCENTRATED LIME-SULPHUR WASH.

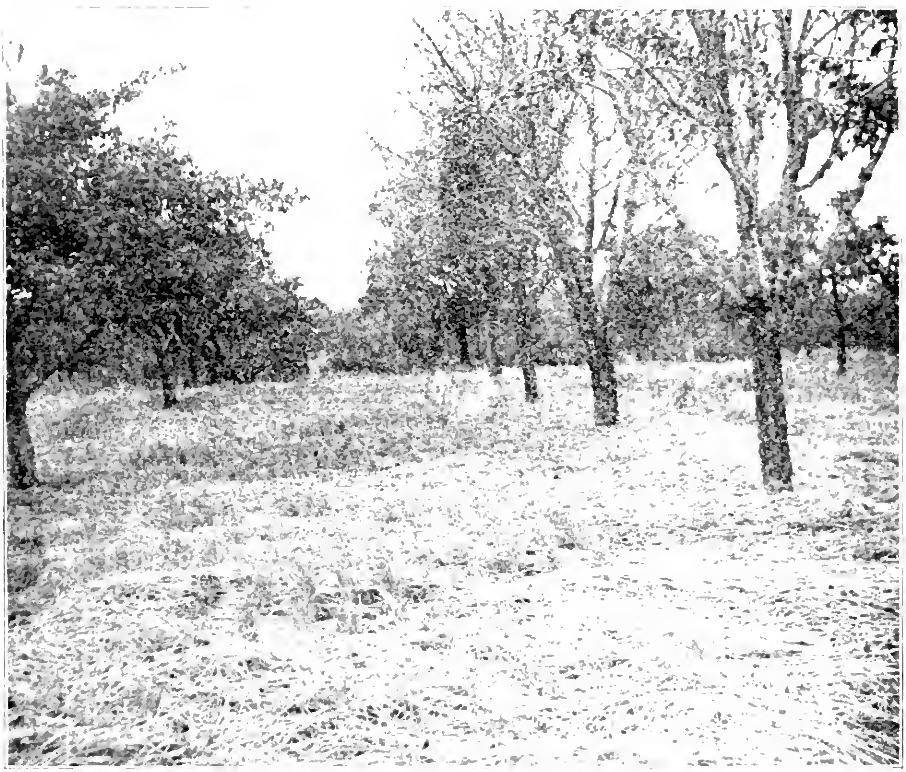
To spray for San Jose and other scale insects.		Summer Sprayings for Apples, Cherries, and European Plums.	
If Baume test is	Amount below should be diluted to 50 gallons.	If Baume test is	Amount below should be diluted to 50 gallons.
33	$6\frac{1}{4}$ gallons	33, 32 or 31	$1\frac{1}{4}$ gallons
32	$6\frac{1}{2}$ gallons	30, 29 or 28	$1\frac{1}{2}$ gallons
31	$6\frac{3}{4}$ gallons	27, 26 or 25	$1\frac{3}{4}$ gallons
30	7 gallons	24, 23 or 22	2 gallons
29	$7\frac{1}{2}$ gallons	21, 20 or 19	$2\frac{1}{4}$ gallons
28	$7\frac{3}{4}$ gallons		
27	$8\frac{1}{4}$ gallons		
26	$8\frac{3}{4}$ gallons	Summer Spraying of Pears.	
25	9 gallons		
24	$9\frac{1}{2}$ gallons		
23	$9\frac{3}{4}$ gallons		
22	10 gallons		
21	$10\frac{1}{2}$ gallons	33, 32 or 31	1 gallon
20	$10\frac{3}{4}$ gallons	30, 29 or 28	$1\frac{1}{4}$ gallons
19	$11\frac{1}{4}$ gallons	27, 26 or 25	$1\frac{1}{2}$ gallons
18	$11\frac{1}{2}$ gallons	24, 23 or 22	$1\frac{3}{4}$ gallons
17	12 gallons	21, 20 or 19	2 gallons

COVER CROPS FOR MICHIGAN ORCHARDS AND VINEYARDS.

Circular No. 18.

BY H. J. EUSTACE.

Trees and vines make most of their new growth from the time the buds open in the spring until mid-summer. During this time, it is desirable that the plant food in the soil be most available and this is secured by the quite general practice of either plowing, harrowing or discing the soil early in the spring and keeping it well cultivated until mid-summer. By ceasing cultivation at this time, the new growth will ripen and harden



Sod mulch system—Barnyard manure spread on the sod.

so that it may not be injured by the low temperature of the winter, as it might be if cultivation were continued until fall and the new wood, thereby, kept soft and full of moisture.

After cultivation is withheld, weeds will start and usually will cover the land, in part at least. But a crop of weeds is unsightly and may

become a nuisance and they do not constitute an addition to the soil, as some other plants do.

It is very desirable to have some "cover crop" growing uniformly upon the soil after cultivation has been stopped. At this time, the trees do not need the plant food or moisture that these "cover crops" will utilize and so they are not competing with the trees but co-operating.

There are numerous plants that are well adapted for cover crop purposes, some more desirable than others, largely depending upon the condition or method of handling the orchard soil or location.

A brief reference to the most common systems of orchard soil management is necessary to understand what kind of plants can be used to the best advantage under the different systems.

In Michigan there are three more or less general systems of handling orchard soils.

1. The sod mulch system. A permanent sod is maintained and as the grass is cut, it is allowed to remain on the ground to decay. Manure or commercial fertilizer when used is applied upon the sod. A mulching of straw is sometimes spread beneath the trees.

Cover crops cannot, of course, be used in this system of orchard soil management.

2. The orchard soil is not plowed but harrowed or disced as early in the spring as practicable.

The soil is kept cultivated by frequent harrowings until mid-summer and at that last cultivation, a cover crop is sown.

Under this system a cover crop plant that dies in the winter is better than one that grows in the spring. It is difficult to work into the soil in a satisfactory way with a harrow or disc, a large live plant. The fruit grower who handles his soils in this way should use for a cover crop, oats and peas, barley, buckwheat or some such plant.

3. The orchard soil is plowed early in the spring and kept cultivated by frequent harrowings until mid-summer when a cover crop may be sown. Since plowing is practiced, a large growth of any plant can be easily handled and plants that live over winter and grow in the spring can be utilized.

The advantages of having a cover crop in an orchard or vineyard are generally well known but important enough to be mentioned again.

1. As has been previously mentioned, their growth late in the season has a tendency to check the growth of the trees and this results in the hardening of the new wood so that it is in good condition for the winter. Trees that grow late in the summer or fall are often very seriously injured by the low temperature of the winter.

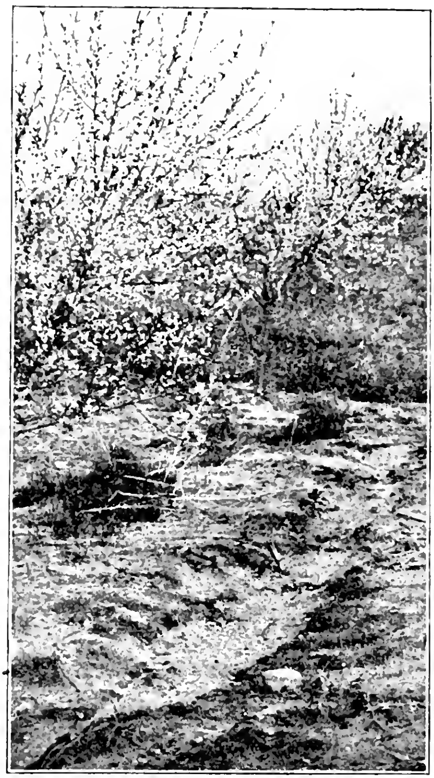
2. The hard rains of both fall and spring will wash the rich top soil very seriously on slopes unless the ground is covered with a good growth of some plant, the roots of which will tend to hold the soil together and prevent the washing.

3. A cover crop will catch the leaves and prevent them from blowing away. In addition to the fertilizer in the leaves, they add humus to the soil. A Baldwin apple tree of bearing age and normal size produced 80 lbs. of leaves, a R. I. Greening 81 lbs., Champion peach 46.28 lbs., Elberta peach 38.26 lbs., Hills Chili peach 52.71 lbs., Kieffer pear 38.62 lbs., Italian prune 19.56 lbs.[1]. Such a mass of material from a tree should be saved on most soils.

[1]New York Agricultural Experiment Station Bulletin 246.

4. As the name implies, a cover crop makes a cover on the land, which is often extremely valuable in lessening the injury that may result from the low temperature of the winter.

This cover of vegetable growth supplemented by the leaves and the snow it holds, will be very valuable in preventing the deep and severe freezing of the soil and tree roots. In winters of exceptionally low temperature, this deep and alternate freezing undoubtedly destroys many trees.



Soil washing where there is no cover crop. A cover of winter vetch in back ground has prevented washing.

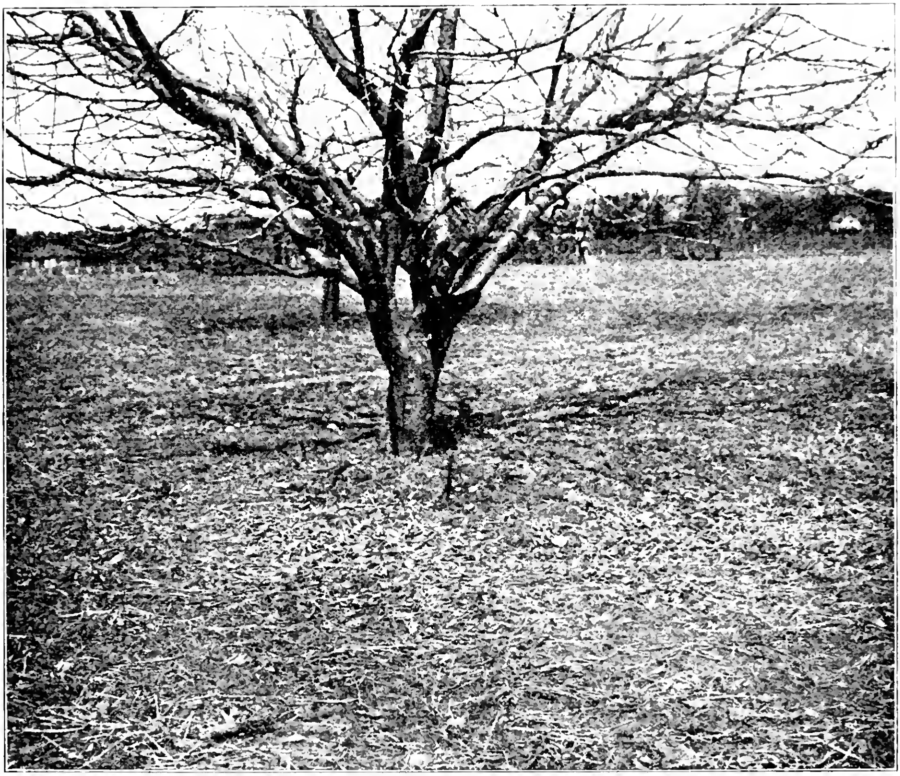
Possibly one of the greatest benefits that results from the utilization of a cover crop in Michigan orchards and vineyards is that they add humus and plant food to the soil.

When a plant is plowed under or worked into the soil with the disc or harrow, it decays and the plant food elements that it contains which have been taken from the soil in the unavailable state are, by the process of decay, liberated and become available. Since the cover crop plant takes up and saves plant food during the fall and early spring, when the tree does not require it, it is really a fertilizer manufacturer. The

legume plants, several of which are used for cover crops have the power of gathering nitrogen from the soil and air and storing it until they decay. As nitrogen is a valuable plant food element, legumes are especially desirable for cover crop plants.

CHOICE OF A COVER CROP PLANT.

The selection of a plant for cover crop purposes depends in the first place, on what system of soil management is followed. In orchards that



A cover crop of buckwheat holding the leaves. Photo, April, 1912.

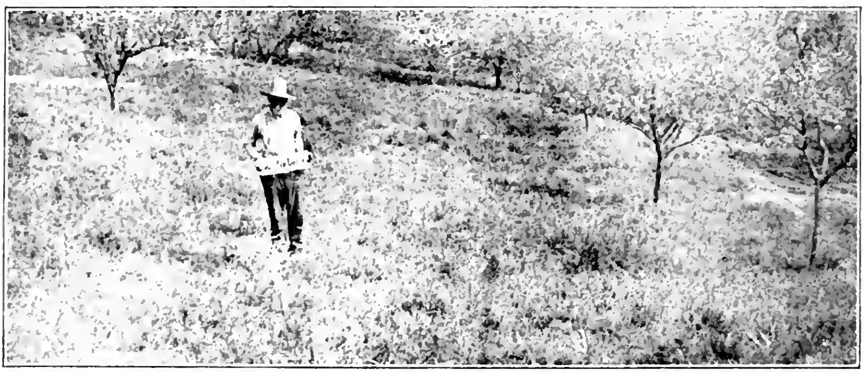
are plowed, a plant can be used that lives over winter and makes a large growth early in the spring before plowing time. A cover crop plant that dies in the fall is much easier to work into the soil by the harrow or disc than a heavy green crop. Where this system, instead of plowing, is practiced, oats and peas, buckwheat, barley or rye should be used. Rye lives over winter and grows in the spring but it can be worked into the soil with the disc without much trouble.

When orchard trees are growing too rapidly, or are making too much wood at the expense of fruit production, it would not be advisable to use a legume plant, as the clovers, vetches, peas or beans. This class of plants add considerable amounts of nitrogen to the soil. It is this ele-

ment of plant food that stimulates a tree into wood growth. In such an orchard some non-legume plant as buckwheat, oats or rye would be better. It may be advisable in some orchards to rotate the use of the cover crop, using a nitrogen gatherer one or two years and the third year use a non-nitrogen gatherer.

The locality of the orchard is important. Some plants that are very desirable for a cover crop will not grow enough to be successful in the northern part of the fruit growing section of Michigan.

The requirements for a cover crop plant are several and the conditions under which they are expected to grow are quite variable. A plant that comes the nearest to fulfilling the particular conditions, should be selected. The best plant is one that starts to grow quickly and is not difficult to secure a uniform stand, even in partial shade. It must withstand a possible drought. It must withstand the tramping of picking



Winter vetch cover crop in Mason Co. sown Aug. 4, 1910. Photograph made May 18, 1911. Soil washing prevented on side hill.

time. It must make at least a fair amount of growth in the late summer and fall. The seed cannot be too expensive or difficult to secure in large quantities. If the plant is the "live over winter" kind, it must be hardy enough to stand a low temperature, possibly without much snow for a protection.

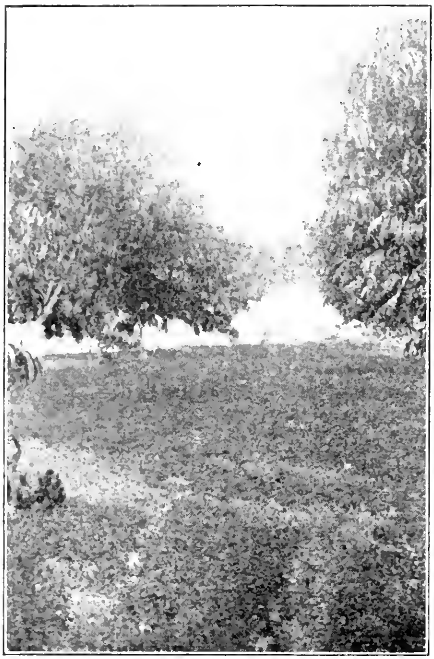
For the past few years the Horticultural department has been making tests of various plants for cover crop purposes. These tests have been in orchards of various ages and on different soil types, and located in various parts of the state.

WINTER VETCH. NITROGEN GATHERER.

This plant is sometimes called hairy or sand vetch. It is a European plant and practically all the seed is now imported from Germany. It has been used for many years in the South as a forage plant and during the past few years has been gaining favor in the North for cover crop purposes.

It should be sown in late July or early August; it is very easy to secure a uniform stand; the seed does not need to be inoculated. It withstands the possible late summer dry spell and the tramping by pickers

and packers at harvesting time. It does well upon a variety of soils but appears to succeed better upon a sandy soil than upon a heavy clay. It does not grow very large in the fall and for this reason it is well to sow a bushel of oats or rye per acre at the time the vetch seed is sown. The oats will make a quick growth or "catch crop" and die late in the fall, the rye will live over winter and grow in the spring. It has been tried from Emmet county to Berrien county and has not winter-killed except in a very few much exposed knolls. It adds a large amount of nitrogen and humus to the soil. In May, 1911, the crop not including roots on one square yard was 5 lbs., equal to 12 tons per acre.



Mammoth clover sown Aug. 20, 1910. Photo Oct. 12, 1910.

Mammoth Clover. Same orchard as sown on left. Condition on May 18, 1911.

The difficulty of plowing under this heavy growth in the spring will not be troublesome if done at the proper time. Should the growth be excessively large, use a chain or rolling coulter upon the plow.

Good results have been secured from the use of 20 to 25 pounds of seed sown broadcast and if drilled, the amount can be reduced to 18 pounds or possibly 15 pounds with a bushel of oats.

It is hoped that Michigan fruit growers who have not yet tested this promising plant for a cover crop, will do so this season.

SPRING VETCH. NITROGEN GATHERER.

This plant is sometimes confused with the winter vetch. To the casual observer, it looks similar. If sown late in July or early in August and a liberal amount of seed (90 pounds per acre) is used, a very heavy

and uniform cover crop may be secured. The plant winter-kills and by spring there is little left to work into the soil. For plowed orchards it is not as valuable as winter vetch and it does not seem to be as valuable as oats and peas for orchards where a cover crop that does not live over winter is wanted.

MAMMOTH CLOVER. NITROGEN GATHERER.

While mammoth clover often makes a very fine cover crop, it is not as dependable under as many conditions as the winter vetch.

To secure a good "catch" of mammoth clover, there must be a well prepared seed bed, which will be made possible if the spring and early summer cultivations were frequent. If the weather conditions are favorable during the late summer and fall, a fairly good growth will be secured. It is checked by the cold. A large growth will be made in the spring if there is an abundance of moisture and under such a condition, the plowing can and should be delayed until the clover has attained a good size. But upon many of the Michigan orchard soils, owing to a lack of moisture, it will not be practicable to delay the plowing until the plant has grown to even a fair size and this is especially true during a spring when the rainfall is light.

Mammoth clover appears to do better upon a clay soil than winter vetch. It has proven hardy in our tests. Not less than 20 pounds of seed per acre should be used.

CRIMSON CLOVER. NITROGEN GATHERER.

Crimson clover has not been a success as an orchard cover crop in Michigan, except in the southern counties. In a few tests in the northern part of the state, we have secured good stands, but it cannot be relied upon. This uncertainty is due to its lack of hardiness. It so often winter-kills that in the spring it is "patchy."

We have tested the scheme of sowing buckwheat with the clover to prevent winter injury. The buckwheat would make a quick growth and in the winter serve as a protection to the young plants. The scheme has not proven successful in our tests. The crimson clover being as "patchy" where the buckwheat was sown as it was where it was not.

The plant might be utilized in orchards in the southern counties of the state but we would not suggest its use in the northern districts.

In cultural requirements and habit of growth it is similar to the mammoth clover and the same amount of seed, 20 pounds per acre, should be used.

COWPEAS OR VELVET BEANS. NITROGEN GATHERERS.

We have tested cowpeas for several seasons and have not found them satisfactory for a cover crop under Michigan conditions. The plants are killed by the first frost and this occurred before they have made even a fair sized growth, even when sown as early as possible and supplied with a quick acting commercial fertilizer.

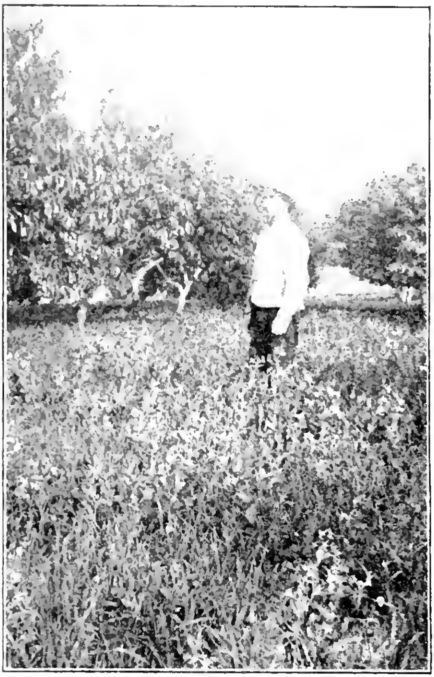
We have had similar experience with the velvet bean.

CANADA PEAS. NITROGEN GATHERER.

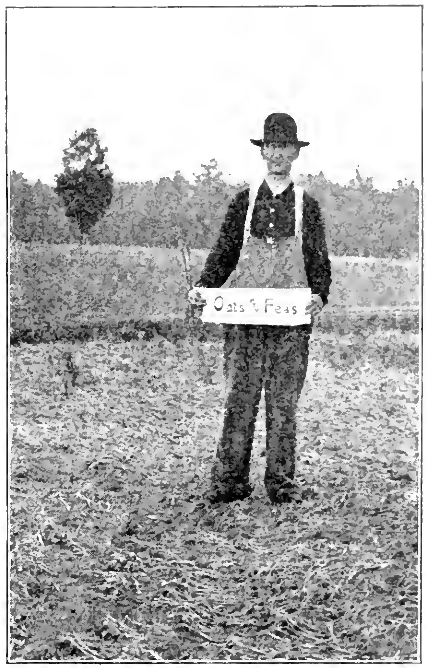
It is much better to use Canada peas with oats and they will be discussed later.

ALFALFA. NITROGEN GATHERER.

Alfalfa is sometimes suggested and occasionally used as a cover crop. It is not adapted for such a purpose and should not be used. It is too difficult to get a good stand and when once secured too valuable to plow the following spring. The alfalfa roots are exceedingly tough and the plowing is very difficult.



Oats and peas cover crop. Sown Aug. 11, 1910. Photo, Oct. 12, 1910.



Oats and peas same orchard shown in picture on left. Condition on May 18, 1911.

BUCKWHEAT. NON-NITROGEN GATHERER.

Buckwheat is reliable as a cover crop. A uniform catch is secured without difficulty, even on a hastily prepared seed bed, it grows quickly and usually attains a good size before it is killed by the frost and after this the stalks stand erect until early winter so the leaves and snow are caught and held. The plant does well on a great variety of soils, both those that are well supplied and those that are deficient in plant food and humus. The root system of buckwheat is large and the roots fine and they leave the soil in a good condition after plowing or harrowing. Since buckwheat grows so rapidly it can be sown a little later than most other crops. One bushel or 48 pounds of seed per acre will give a fine, heavy stand.

RYE. NON-NITROGEN GATHERER.

Rye will probably succeed better under more unfavorable cultural conditions than any other plant used for cover crop purposes. It does well upon poor soils that are deficient in humus and upon new and "rough" or poorly prepared soils. It is useful upon very dry soils as well as on those abundantly supplied with moisture. It will make a fair growth during the fall and will start to grow early in the spring, so by the time the plowing or harrowing should be done, there is a good, heavy growth to turn under. The large size of the plant does not interfere with plowing nor is it difficult to work it into the soil by discing.

Plowing or discing should be done by the time the head begins to form, if delayed after this time, the plant draws heavily upon the soil moisture and it becomes so hard and tough that it does not decay for a long time.

One bushel of seed, or 48 pounds per acre, will give a good stand.

Rye cover crop in vineyard, Van Buren Co.

OATS OR BARLEY. NON-NITROGEN GATHERERS.

Oats are frequently used alone for a catch crop. The seed is not expensive, easily obtained and is much better than nothing or weeds. They can be sown late and will make a good cover and on this account, sometimes have to be resorted to in a very dry or otherwise unfavorable summer. But a combination of oats and winter vetch or oats and peas is much better.

A bushel of oats per acre whether alone or in combination will make a good thick stand.

Barley is frequently used for a catch crop and makes a little heavier growth than oats. The seed is not as easily obtained which is probably one reason why it is not used more. The same amount per acre is used.

OATS AND PEAS.

A combination of oats and Canada peas make a very desirable catch crop and it is used quite largely in orchards that are disced or harrowed

instead of plowed. The plants make a large growth before they are killed in the fall and the dead tops are easily worked into the soil in the spring.

Since these plants make a good growth quickly, they are valuable to use where the catch crop has by necessity to be sown somewhat late in the summer.

Use one bushel of oats and one bushel of Canada peas per acre. The combination is much better than either plant alone. The oats are non-nitrogen gatherers and the peas are nitrogen gatherers.

These seeds can be purchased of any seed dealer. Orders should be placed as early as possible, especially for winter vetch seed. This is practically all imported and the supply is limited.

Seeds will be tested for their purity by the Botanical department of the Michigan Agricultural College, East Lansing.

CUCUMBERS AS A CASH CROP.

Circular No. 19.

To produce cucumbers profitably demands a location near a good sized town or a salting station and where enough help to do the picking can be secured. The crop will do well on a variety of soils. If planted on soil that is inclined to be light and also deficient in humus, the yield may be shortened unless rain is plentiful during July, August and September. If planted on heavy clay, the plants may suffer in a wet year from the soil becoming hard and packed, caused by tramping while picking the cucumbers. A clay loam that is well supplied with humus or decayed vegetable matter is very satisfactory. If it is tile drained, so much the better for at picking time, one must get on the ground to pick no matter how wet the soil may be.

A clover sod plowed early, worked down and harrowed occasionally until planting time makes a good seed bed. Timothy sod handled in the same way is also suitable if it is not too badly infested with cut worms. In fact, any soil intended for cucumbers should be plowed early and kept well worked till planting time. Such a method of handling pays for several reasons:

First.—It helps rid the soil of weeds. When soil is plowed, rolled and worked down reasonably fine, millions of weed seeds will germinate in a few days which can be destroyed by harrowing on a bright day. A second harrowing a week later will destroy a second lot of seedlings. A third and fourth harrowing will destroy a third and fourth lot of seedlings and the fourth lot will just about rid the top soil of weed seeds. The *cheapest, quickest and best way* to cultivate a crop is to harrow the soil before the seed for that crop is planted.

Second.—Keeping the soil well worked conserves moisture and enables the seed to germinate no matter how dry the weather may be at planting time. Soil that has not been plowed or worked until it is needed for planting is quite likely to be dry and full of clods. By the time these clods have been worked down sufficiently fine, the top soil has lost much of its moisture. Such soil might do as a seed bed for corn or for any crop with large seeds which may be planted quite deeply, but it will not be satisfactory for cucumber seeds which should not be planted over an inch deep. Soil which has been plowed early and harrowed occasionally will be moist an inch below the surface, even during a very dry time. Seed planted in such a soil will germinate readily and produce an even stand of vines which is worth a good deal to any grower.

Third.—Early plowing and frequent harrowing will put the soil in such a physical condition that it will not pack and bake after every rain. It will become loose, mellow and friable; rain falling upon it will drain away, leaving it in practically the same condition as it was before the rain, while a rain upon freshly plowed ground is quite

likely to cause a crust to form. If seed has just been planted or if the young plants are just up, such a crust will be very injurious.

Fourth.—Early plowing and frequent harrowing makes the plant food in the soil more available and plant food must be in solution before plants are able to use it. The more finely divided a substance is, the more readily will it dissolve. This clearly illustrates why a well prepared seed bed has advantages over lumps and clods. Harrowing the soil aerates it, that is, it enables the air to enter the soil more readily. Besides, soil contains minute forms of plant life, known as bacteria, which only thrive and multiply in the presence of air. These bacteria are beneficial inasmuch as they break down complex forms of plant food and make it more quickly available for the plants' use.

Cucumbers are not hard on the soil but to be a successful crop the soil should be quite rich. They are quick growing plants and have not the time to rustle for a living, nor can the grower afford to have them do so. The thing to do is to provide them with an abundance of plant food so that they may grow, as it were, at high pressure. On the average land, they should not follow sugar beets, cabbages, potatoes or oats unless such land has, in the mean time, received a liberal application of barn-yard manure or commercial fertilizer.

No fertilizer material gives better results than well rotted stable manure. If it is plentiful it may profitably be spread broadcast and plowed under, but if the supply is limited, it will be most economical if applied in the hills.

If commercial fertilizers are to be used, the ground should be plowed early and the fertilizer drilled broadcast as early in the season as possible. When the cucumbers are to be grown for pickles, a fertilizer of the following composition is recommended.

Nitrogen	3 to 4%
Available Phosphoric acid	8%
Potash	6 to 10%

About one-half of the nitrogen should be in the form of nitrate of soda and the remainder as readily available organic nitrogen, such as dried blood or high grade animal tankage. A fertilizer of about this formula can be readily obtained of any manufacturer. From 500 to 1000 pounds, depending upon soil conditions, should be used per acre.

In using commercial fertilizers, it should be remembered that the best results will be obtained when they are used upon soils that are in good physical condition and well supplied with organic matter.

Unless manure is to be used in the hills, a corn marker with teeth six feet apart is all that is necessary to mark the rows. Six by four feet is the ordinary distance when planting in hills is practiced and if it is desired to cultivate both ways, simply mark both ways and plant at the intersections of the marks. When manure is to be used in the hills, mark in the same way, but the rows six feet apart will have to be furrowed out with a walking plow. Throw a forkful of manure in the furrow at each intersection and cover with a hoe after having first packed the manure with the feet or the back of the hoe. The manure should be put in the hills as early as possible but in harrowing the soil after they are made and before planting, care should be taken not to entirely fill the furrows so as to obliterate the rows.

When a large acreage is grown, the practice is to double furrow the row, that is, plow a dead furrow every six feet. In this furrow distribute the manure with a manure spreader, using the attachment to narrow up the discharge. Cover the manure by plowing a back furrow upon it. Roll as soon as possible and drag the ridge with the rest of the field, dragging lengthwise of the rows. The seed may be planted in hills upon this ridge or a garden drill may be used and a continuous row sown. There should be a plant every two or three inches and these should be thinned to a foot or eighteen inches as soon as all danger from the cucumber beetle is over. A continuous row has some advantages over hill planting but if the ground is inclined to crust, the young plants will have more difficulty in breaking through than if they were planted in hills. The ground is more evenly occupied and the roots are not so crowded. Such a row is also easier to pick especially if, when the vines have run about two feet, they are placed at right angles to the row. Cucumbers should be cultivated to destroy weeds and to maintain a dust mulch. Any cultivator suitable for corn will do the work but the teeth should be set more shallow for cucumbers than for corn. It is better not to work too close to the plants with the cultivator, and if the soil crusts and there are weeds in the hills, they will require one or two hand hoeings. It will pay well to cultivate often enough to maintain a good dust mulch.

When cucumbers are grown under contract, the company usually reserves the right to choose the variety that shall be planted by their growers. This is done for two reasons: (1) If each individual grower was permitted to choose the variety he should grow, there would be a great many varieties planted which would result in a lack of uniformity in the cucumbers delivered to the salting stations. (2) Most pickling companies market the bulk of their small cucumbers in glass jars or bottles. They have found that only three or four varieties produce suitable cucumbers for this purpose.

Boston Pickling, Chicago Pickling and Snow's Perfection are the three varieties that are usually grown under contract. They are prolific yielders, producing their cucumbers in clusters.

When cucumbers are grown to be sold direct to the consumer or to a retail grocer, some strain of the White Spine is generally grown. This is a prolific variety which yields fine straight cucumbers but which are a little too large in diameter to be suitable for bottling. This is also a good variety to grow when it is desired to produce early "slicers." Slicers are the large cucumbers suitable for slicing and are eaten fresh.

Some of the Long Green strains will produce "slicers" of better quality but not so early in the season as the White Spine. They are freer from seeds and the flesh is firmer and when well grown, they will compare favorably with hot house cucumbers. Varieties suitable for hot house culture are not adapted to be grown under field conditions.

Usually cucumbers are planted about June 1st and picking will begin the latter part of July or the first of August, depending upon the thriftiness of the vines. The first two or three pickings will hardly pay for the gathering but it is very necessary to remove them for the good of the vines. The fewer the cucumbers that are allowed to become full grown, the better will the vines bear. Very few growers realize what a bad effect it has upon vines to allow the cucumbers to become

over-grown or the injury that may be done in careless picking, which results in tearing and breaking the vines. In average growing weather, 48 hours may intervene between pickings and later in the season, 72 hours may not be too long. This is assuming that the vines are picked reasonably clean at each picking. It is impossible to find and remove every cucumber at any one time, but that should be the aim. Large cucumbers in which seeds are forming, sap the vitality of the vines and a plant that has produced seeds becomes inactive and soon ceases to grow, but just as long as it is prevented from producing seed, it will endeavor to do so. The result is that small cucumbers in abundance will continue to form until the vines are killed by frost.

There are so many factors which influence the yield that it is unwise to try to tell any prospective grower what he will get in bushels per acre. This much is certain, however, one acre of vines that is kept well picked will produce more bushels and, therefore, a much greater net profit than will two acres of as equally good vines which are only indifferently picked. Two hundred bushels of marketable cucumbers is the average yield of one Michigan grower over a period of nearly twenty years. This was on a large acreage, so any fairly intelligent grower who does not plant too extensively should be able to secure such yields.

What are some of the advantages in raising cucumbers? If they are grown under contract, they are a cash crop and the grower does not have to worry about the state of the market; each picking is turned into cash as soon as delivered. Picking comes after grain harvest and before corn harvest or in what is generally a slack time on most farms. Unlike sugar beets, there is very little money invested in the crop before returns are made. Picking is the chief item of expense and until picking begins, there is very little expense attached to the crop. Unlike potatoes, cucumbers are sold at a guaranteed price and a large crop does not depress the market. No extra machinery is needed to handle the crop. The implements usually found upon the average farm are all that is required to take care of the crop from start to finish. The cost of seed is insignificant.

There are three of four insects which feed on the cucumber vine or its fruit. The striped cucumber beetle (Diabrotica vittata) attacks muskmelons and early planted cucumbers but does not work extensively in the main or late crop plantings. Most growers plant four or five times as many seeds as they desire plants which allows the beetles to take some without ruining the stand. If the beetles work too badly, the vines may be dusted, preferably while the dew is on, with nine parts air slacked, or still better, hydrated lime and one part arsenate of lead *powder*. Paris green should not be used as it may burn the vines. Coating the plants with a spray of six pounds arsenate of lead paste to fifty gallons of water makes them distasteful to the insects.

There is a plant louse which attacks cucumber vines. It is a sucking insect, so cannot be destroyed by applying a stomach poison, but must be killed by a contact spray if killed at all. If the first few hills affected are buried, vines and all, it will do much to control the pest. Keeping the vines thrifty is also a decided help since the louse always prefers to feed on sickly and stunted hills. Eight pounds of whale oil soap to fifty gallons of water makes a good spray but usually the enemies of the louse will hold it in check.

The Downy Mildew of the cucumber is a fungous disease (Plasmopara

cubensis) which is most prevalent during a season of excessive rainfall like the one of 1912. It is first noticed as small brown spots on the oldest leaves. These spots increase in size until nearly the entire leaf is affected, becoming dry and dead. The injury results from the plants losing more or less of their foliage. Spraying with a dilute solution of Bordeaux mixture made of two pounds of copper sulphate and four pounds of lime to fifty gallons of water, will control the disease to some extent, but the treatment must be thorough and is preventative rather than curative. Commence spraying when the vines have runners a foot long and spray once a week until it is impossible to drive through the rows. In an average season, the loss from the mildew has not been serious even when spraying is not practiced.

One man can pick the cucumbers from one acre of vines by picking one-half acre daily. School children will be able to pick half as large an acreage as a grown person. Many growers allot their children a small plot of ground for cucumber raising, the profits from which are their own.

To make a success of growing pickles, observe the following conditions: Fit the ground thoroughly, use enough well rotted manure to produce thrifty, strong growing vines; plant intensively rather than extensively; and aim by clean picking to prevent the forming of large cucumbers.

WALTER POSTIFF.

Mr. Postiff, the author of this circular, graduated from the Michigan Agricultural College in 1909. For a number of years before and since that time, he has had experience in producing cucumbers commercially.

H. J. EUSTACE,
Horticulturist.

STARTING A LAWN.

Circular No. 20.

There is nothing in the decoration of the home grounds that is so pleasing and beautifying as a good lawn.

CONSTRUCTION.

Soil.—The soil for a lawn should be of good texture containing plenty of plant food and enough humus to retain moisture. A strong clay loam or a sandy loam with a clay subsoil most nearly approaches these conditions. When a lawn is to be constructed upon light sandy soil, a top dressing of about two inches of clay with a heavy application of well rotted manure should be mixed with the first three to four inches of sand. Frequently, in building a house, the soil excavated from the cellar is spread about covering the good top soil with a poor sub-soil. This sub-soil is of poor texture, contains little available plant food and is an extremely poor soil for lawns. Where it is necessary to use this sub-soil for filling, the top soil should be first removed to be later used as a surface dressing.

Grading.—In the grading of a lawn, first endeavor to obtain good surface drainage, see that there is a slight slope away from the buildings; that there are no low pockets where water may stand during the winter and spring, and that the area as a whole, is either naturally or artificially well drained.

Except in some very special cases, a level lawn should not be constructed. It lacks naturalness and decreases the apparent extent of the lawn. In grading, endeavor to preserve the slight natural slopes and curves of the land, remembering that nature never produces perfectly level surfaces. This part of the grading should be carefully studied and considered before starting the work. The way in which it is done will determine whether a graceful, pleasing, natural lawn is secured or a stiff, restrained, unsatisfactory one is the result.

After the general slopes have been established, the land may be harrowed if necessary and any small uneven places leveled off.

If the land has been allowed to remain over winter in the rough condition, the soil will have become well settled by spring and will be ready for the final work before seeding. Pick off all the stones which have come to the surface during the winter and then go over the land with a shallow harrowing or raking. If it can then be rolled, the small uneven spots will become very apparent and they can then be leveled off with a hand rake. By re-rolling and re-raking the land in this way, the surface can be made as smooth and even as desired.

Fertilizers.—Well decomposed stable manure is the best general purpose fertilizer for lawns. It contains all the chemical elements essential for plant growth and adds humus to the soil, thus making it more

retentive of moisture and also improving its texture. If this can be used, a heavy dressing should be applied. A ton to two thousand square feet would not be too heavy.

Chemical fertilizers may be used to advantage after the grass is well started but should never be applied at the seeding time as it may kill the young roots which come in contact with it during germination. It must be remembered also, in using commercial fertilizers that they never improve the physical condition of the soil. There is no humus added to the soil by their use and hence the soil texture is not improved. It is simply an addition of the essential food elements and should always be regarded as such. It is easily applied, contains no weed seeds and may be readily obtained.

Some of the most desirable forms of chemical fertilizers for lawns are fine ground bone, wood ashes, and the high grade forms of complete fertilizers. Ground bone is a very good form of fertilizer for lawns and although it contains principally phosphoric acid, it furnishes some nitrogen and lime. Unleached hardwood ashes is used as a source of potash and if applied each spring soon after growth begins, will generally prove very beneficial. Complete high grade fertilizers for lawns may be obtained from almost any fertilizer dealer and, while more expensive than the other forms, they are often quite efficient in maintaining the lawn.

Although the amount of fertilizer advisable to apply will depend much upon the condition of the soil as well as upon the form and strength of the fertilizer to be used, a dressing of about 2.5 pounds per hundred square feet would be a moderate application under average conditions.

VARIETIES OF GRASS FOR LAWNS.

The best variety of grass for lawns, under general conditions in Michigan, is Kentucky bluegrass (*Poa pratensis*). While it is rather slow in starting, it produces a permanent lawn of fine texture and of a rich green color. The crown of the plants set very close to the ground thus permitting close clipping and the plant, after becoming established, spreads rapidly by underground roots.

Although a permanent bluegrass lawn may be desired, it is often advisable to sow other varieties with the bluegrass seed. Of the rapid growing grasses that may be used for this purpose, the English rye grass (*Lolium perenne var. tenue*) is one of the best. It is an annual grass and a little coarse in leaf, but starts rapidly, produces a very early effect and covers the ground which might otherwise be occupied by weeds. Do not use oats, rye or timothy for this purpose.

Redtop (*Agrostis alba*) is a quick growing grass which produces a good lawn effect the first season. It is of a finer texture than rye grass but does not grow quite as rapidly on the start. It grows better under adverse soil and moisture conditions than most other grasses.

White clover (*Trifolium alba*) is frequently used on lawns as many people desire the appearance of the white clover blossoms in the summer. Others object to its tendency of giving the lawn a spotted effect.

On a very sandy soil the Rhode Island Bent grass (*Agrostis canina*) does well, while in very shady places the Woodland Meadow grass (*Poa nemoralis*) may be used. Where the lawn is on high, dry situations or slopes the Sheeps fescue (*Festuca ovina*) will be found desirable, while

on low wet places the Various-leaved fescue *(Festuca heterophylla)* will thrive.

For the average lawn, a good mixture is one-fourth Fancy Red Top, one-fourth English Rye grass and one-half Kentucky blue grass. If the area to be sown is small and the conditions of soil or exposure somewhat variable, it is advisable to buy a high grade prepared lawn mixture from a reliable seedsman. This mixture will generally contain seed adapted to various conditions and will prove more convenient and frequently better than the homemade mixture on such a small scale.

Frequently grass seed contains a great many weed seeds, often of a kind that may prove a serious nuisance and expense to get out of the lawn if they once become established. It is best to buy only the best seeds from the most reliable seedsmen. If a large quantity is to be procured, it would be advisable to send a sample to the Division of Botany of the State Experiment Station where it will be examined for purity free of charge.

Sowing the Seed.—In starting a lawn use plenty of seed, one pound to about 1000 square feet or fifty pounds to the acre (42560 sq. ft.) being none too much. Thick seeding chokes out weeds and assists in producing a quick effect.

Select a day when there is no wind to sow the seed. Early in the morning or about sun down is a very good time, and if just before a rain, so much the better.

By sowing the seed in the following way, an even stand is quite assured: taking one-half of the amount of the seed to be sown and beginning at one end of the lawn, sow in parallel strips until the entire lawn is covered; then take the remaining one-half of the seed and sow in strips in the other direction. If this is properly done, there should be no streaks or vacant spots in the future lawn.

After sowing the seed, unless directly followed by rain, the soil should be rolled. Raking or harrowing after sowing is apt to bury the seed unevenly.

Maintenance.—After the grass has grown to a height of from four to six inches, it should be given the first clipping, being careful not to cut very close. A scythe is better for this cutting than a lawn mower as it will not pull out the young plants or cut as close as the mower. The future cuttings should be performed frequently enough to permit the clippings to remain on the lawn without being unsightly. These clippings, if allowed to remain, will form a dense mulch around the base of the plants and protect the soil from drying out during the summer months. Cut frequently then but not too close.

Additional seed should be applied to all lawns at least every spring and often another sowing would prove beneficial the latter part of June or in September.

The most effective method of controlling weeds in lawns is by securing good drainage to the soil, keeping the lawn well supplied with plant food and the soil well filled with pure seed. Make the conditions for plant growth most favorable and there will be little chance for weeds to gain a foothold and develop.

C. P. HALLIGAN,
Assistant Horticulturist.

NEUTRAL AMMONIUM CITRATE SOLUTION

Technical Bulletin No. 12.

A. J. PATTEN AND C. S. ROBINSON.

Since the proposal of the ammonium citrate method for the determination of available phosphoric acid, much trouble has been experienced in preparing a strictly neutral solution of the reagent. The weakness of both the acid and the base renders the end point quite indistinct with ordinary indicators, and much time and patience are required on the part of the operator to obtain the desired results. Several modifications of the simple titration method have been proposed, but each has objections which prohibit its common acceptation by practical chemists. The importance which the method has assumed in agricultural work demands, however, that some convenient means be devised for preparing the necessary solution. Such a method has recently been proposed by Hall and Bell[1] and was later shown by Hall[2] to be quite suitable for laboratory use. At the time these articles appeared, the authors of this paper were engaged in working out the same method, and the results are here offered, not with the hope of claiming the credit for originating the method, but simply as corroborative evidence in favor of its general adoption.

Of the several methods proposed as substitutes for the present official method, that recently suggested by Hand[3] using purified litmus solution or azolitmin seems to be the most promising. In order to test it out and compare it with the official corallin method as well as to obtain some data as to the accuracy of the latter an acid solution of ammonium citrate was made up and neutralized by these two methods by each of four analysts working independently.

An acid citrate solution was chosen of which 50 c.c. required 7.50 c.c. of the dilute ammonia solution for neutralization as determined by the conductivity method to be described later. The dilute ammonium hydroxide solution (about 3 per cent) was kept in a burette enclosed in opaque paper to prevent the reading being taken until the supposed neutral point had been reached. In this way each operation was made independently of the others. Great care was taken that no loss of ammonium hydroxide should occur during the process. The results are given in Tables I and II.

[1]Jour. of Am. Chem. Soc. 33, 711 (1911).
[2]Jour. of Ind. and Eng. Chem. 3, 559 (1911).
[3]U. S. Dept. of Agric. Bur. of Chem. Bul. 132, P. 11.

TABLE I.

With corallin as the indicator.

Number.	Cubic centimeters dil. NH_4OH per 50 c. c. sol.	Number.	Cubic centimeters dil. NH_4OH per 50 c. c. sol.
P I	12.30	M I	16.00
P II	12.10	M II	15.00
P III	16.20	M III	16.40
P IV	12.70	M IV	16.60
R I	12.00	I I	12.20
R II	12.00	I II	13.60
R III	14.30	I III	19.60
R IV	13.60	I IV	15.90

TABLE II.

With purified litmus as the indicator.

Number.	Cubic centimeters dil. NH_4OH per 50 c. c. sol.	Number.	Cubic centimeters dil. NH_4OH per 50 c. c. sol.
P I	15.00	M I	14.00
P II	13.76	M II	15.00
P III	16.00	M III	12.50
R I	15.00	I I	15.82
R II	17.50	I II	15.82
R III	14.00	I III	15.00

An inspection of these results reveals the fact that the official method gives extremely inconsistent results, even in the hands of one person. In only one case was an exactly neutral solution secured. The variation in the results obtained by one analyst using this method amounted to seventy-four cubic centimeters of the dilute ammonium hydroxide solution per liter of the acid citrate solution. While this is the maximum variation in the four sets of determinations given, it must, nevertheless be accepted as a possibility in actual practice. Such a condition is surely anything but desirable and demands immediate attention. The other method showed to much better advantage. Not only were the results more consistent, but one-third of the trials actually gave neutral solutions.

These examples fairly illustrate the difficulty in making an exactly neutral reagent by the methods most commonly in use and it is quite possible that in many cases the character of the "neutral" ammonium citrate solution varies more than in the cases cited and that considerable error may be introduced into determinations in this way. It is evident that not only is there a wide variation in the solutions made by different individuals, but that even the same person can rarely duplicate his own results.

It has long been realized that it was impossible to get consistent results in neutralizing ammonium citrate solution by the official method, but it has been assumed that the differences in the acidity of the solution

were too small to cause any appreciable error in determinations made with them.

In order to test the correctness of this assumption several actual determinations were made. The solutions used were R II, C,[1] M IV, and I III. They were carefully diluted to a specific gravity of 1.09 and the determinations were all made at one time so that there could be no variation due to temperature of the bath. Determinations were made on two samples of fertilizer, one containing a small percentage of insoluble P_2O_5 and the other a large percentage. The results are given in Table III:

TABLE III.

Number.	Cubic centimeters dil. NH_4OH per 50 c. c. sol.	Sample 1 Insol. P_2O_5 per cent.	Average.	Sample 2 Insol. P_2O_5 per cent.	Average.
		2.84		8.86	
		2.81	2.83		8.84
R II	6.00	2.83		8.82	
		3.54		9.82	
		3.80	3.69		9.81
C	7.50	3.71		9.80	
		4.23		10.10	
		4.07	4.17		10.04
M IV	8.30	4.21		9.98	
		4.79		10.56	
		4.77	4.82		10.46
I III	9.80	4.90		10.36	

An inspection of these results shows a marked relationship between the reaction of the ammonium citrate solution and the amount of phosphorus pentoxide extracted.

These variations amounting to 1.99% in one case and 1.62% in the other are certainly significant. The results prove that perfect neutrality of the citrate solution is of the utmost importance in securing consistent results as the above differences are of sufficient magnitude to make the method extremely uncertain.

CONDUCTIVITY METHOD.

The above mentioned method proposed by Hall and Bell was found to be much more satisfactory.

It depends upon the fact that when different quantities of alkali are added to an acid solution (or vice versa) the electrical conductivity or resistance of the solution will vary with each addition, and if these resistances or conductivities are plotted against the amounts of alkali or acid added, there is a sharp change in the direction of the curve at the neutral point. This property has been made use of for the titration of various liquids where color changes were difficult to observe and has given very good results.

As many chemists have had no experience in determining electrical conductivity, the apparatus and method of procedure are taken up here in detail.

[1]Neutralized by the conductivity method.

The apparatus required for studying these changes is that ordinarily used in determining the electrical conductivity of solutions. It consists essentially of the following:

1. Electrolytic cell.
2. An accurate resistance box.
3. Wheatstone bridge.
4. Induction coil.
5. Telephone receiver.
6. Source of electromotive force, i. e., a small storage cell or dry battery.
7. Telegraph key or switch.
8. Large tank or tub of water, preferably with constant temperature attachment.

There are several kinds of electrolytic cells. They consist essentially of two electrodes of platinum foil to which are fastened platinum wires sealed into glass tubes. The glass tubes may be filled with mercury and the contact made by dipping the ends of the connecting wires into them. The authors used the so-called "Oswald conductivity cell," which gave very good results. Hall and Bell[1] recommended the use of the "H. C. Jones cell for concentrated solutions."

The resistance box may be of the ordinary decade type but should have an accuracy of .1%.

The wheatstone bridge in its simplest form consists of a long wire of resistance alloy connected to terminals at both ends and fitted with a sliding contact. It is mounted on a scale, usually an ordinary meter stick. The best instruments now have this wire coiled on a marble cylinder. They are of two types; one where the cylinder and wire are stationary while the arm holding the sliding contact moves, and the other where the arm is stationary and the cylinder and wire move. Either is suitable for the purpose.

Any small induction coil giving a regular high pitched vibration will do. One such as is used in ordinary medical batteries is quite satisfactory.

The storage cell used by the authors was one made for use on automobiles. Dry cells may be used in place of it.

The fact that electrical resistance varies greatly with temperature makes a thermostat of some sort imperative. Hall has shown that a large tub of water can be used to good advantage, but of course wherever possible a regular thermostat with a constant temperature regulator should be used.

Before proceeding with the actual determination, the platinum electrodes of the cell must be coated with platinum black. The manner of doing this is described by Findlay.[2] The glass cell is first steamed for about an hour to remove soluble salts, after which a solution of 3 grams of platinum chloride and 0.02 to 0.03 grams lead acetate per 100 c. c. of water is placed in it. After cleaning the electrodes with chromic acid, they are placed in this solution and connected with a battery and such a resistance inserted in the circuit that the amount of gas evolved is not too rapid. The current should be passed for 20 to 30 minutes, the wires dipping into the tubes of mercury being interchanged every half minute.

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[1]Loc. Cit.
[2]Practical Physical Chemistry, Longmans, Green & Co., 1906. P. 150.

The coating which is formed should be black and velvety. It is quite essential that a proper coating of platinum black be obtained, for upon the condition of the electrodes depends the sharpness of the end point. Then the electrodes are washed with warm distilled water and replaced in the cell with dilute H_2SO_4 substituted for the platinizing solution. The current should be passed for about the same length of time but need not be reversed so often. The electrodes are then washed several times with warm distilled water and tested to be sure that all soluble material has been removed. This is done by taking several bridge readings, as described below, with distilled water in the cell. These readings should remain constant if the cell is clean, otherwise there will be a gradual rise of resistance.

For determining the resistance of a solution the apparatus is connected as shown in the diagram (Fig. 1).

AB=bridge wire,
C=sliding contact,
R=resistance box,
X=electrolytic cell,
I=introduction coil,
T=telephone receiver,
S=switch or telegraph key.

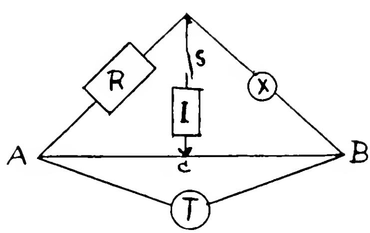

Fig. 1

The cell and electrodes should first be rinsed two or three times with the solution to be tested. A quantity of the solution is then placed in the cell X, and air bubbles shaken out by moving the electrodes up and down and the connections made as indicated.

Before taking the reading the solution must be allowed to come to the temperature of the bath. If the flasks containing the original solution are kept in the bath, this will take only a short time, otherwise the cell and contents should be left in the bath from seven to ten minutes. With citrate solution containing an excess of ammonium hydroxide this period

should not be exceeded, or variations in results will be obtained, due to the escape of ammonia. Finally the switch S is closed and the sliding contact C moved along the bridge wire till the sound in the telephone receiver reaches a minimum. The resistance in R should be arranged so that this point falls near the middle of the bridge. After taking the reading, the cell and the electrodes should be rinsed again two or three times and a duplicate reading taken.

It is generally quite difficult to read the actual point of minimum sound. This is usually obtained by taking two readings, one on either side of the minimum point, having the same intensity. The average of the two readings should give the correct result.

This bridge reading is all that is necessary for the determination of the neutral point in ammonium citrate solution, since it is a constant function of the conductivity and may be used in place of it in plotting the curve. Its use for this purpose does away with all mathematical calculations and makes the determination of the so-called "cell constant" unnecessary. It is necessary only to keep the resistance in the box R the same during each series of determinations and to be careful that the relative position of the electrodes is not disturbed by bending or striking against the edge of the cell.

The method of procedure as given by Hall is quite satisfactory. A solution of citric acid is almost neutralized, the density being kept above 1.09. Small samples of this solution are then titrated with a dilute solution of ammonium hydroxide, using corallin as an indicator, to determine the approximate amount required to neutralize the remaining acid. Definite quantities of the citrate solution are removed with a pipette and transferred to clean, dry, volumetric flasks. To these portions of the original solution varying quantities of the dilute ammonium hydroxide are added in such a way that some of the flasks contain more and some less than the approximate amount required for exact neutralization as determined by the titration with corallin. These solutions are then made up to the same volume with distilled water, placed in a thermostat, the temperature of which is held constant, and allowed to come to the temperature of the bath after which their resistances are measured by the wheatstone bridge method. Plotting the cubic centimeters of ammonium hydroxide against the bridge readings gives a curve from which may be read the exact amount of ammonium hydroxide to neutralize the acid in a given quantity of the citrate solution.

The following are some of the results obtained and illustrate the sharpness with which the neutral point may be read:

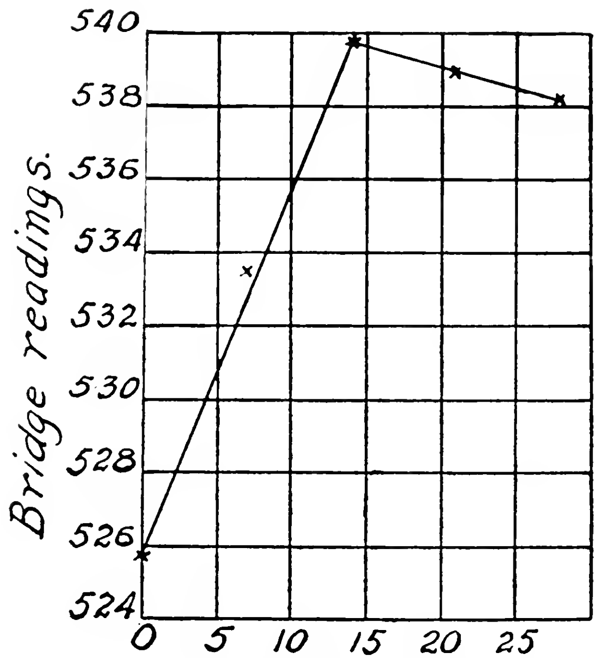

Fig 2.

TABLE IV.

Number.	Cubic centimeters dil. NH_4OH per 50 c. c. sol.	Bridge readings.	Number.	Cubic centimeters dil. NH_4OH per 50 c. c. sol.	Bridge readings.
1	0.0	525.75	4	21.0	539.00
2	7.0	533.50	5	28.0	538.25
3	14.0	539.75	6	35.0	537.25
			Neut	14.0	539.75

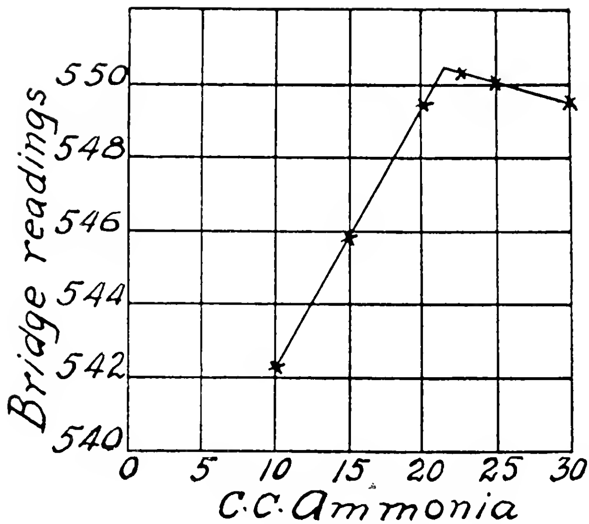

Fig 3.

TABLE V.

Number.	Cubic centimeters dil. NH_4OH per 100 c. c. sol.	Bridge readings.	Number.	Cubic centimeters dil. NH_4OH per 100 c. c. sol.	Bridge readings.
1	10.0	542.25	4	22.5	550.25
2	15.0	545.75	5	25.0	550.00
3	20.0	549.50	6	30.0	549.50
			Neut	21.6	550 35

Accuracy of Method.

In order to test the accuracy with which results may be duplicated by different operators, a stock solution of acid ammonium citrate was made up and analyzed independently by four laboratory assistants, three of whom had never before made any conductivity measurements. One hundred cubic centimeter portions of the acid citrate solution were transferred to 250 c.c. volumetric flasks, the designated amounts of ammonium

hydroxide added and the bridge readings taken. Each operator made four sets of determinations on the same solution, the conditions being altered each time so as to give different readings for each set, thus eliminating any error due to the operator attempting, unconsciously or otherwise, to duplicate his previous results. Each one was required to plot his own results and report independently the amounts of ammonium hydroxide required to neutralize the acid in the quantity of citrate solution taken. The results are given in the following table:

TABLE VI.

Number.	Cubic centimeters dil. NH_4OH per 100 c. c. sol. per 100 c. c.	Number.	Cubic centimeters dil. NH_4OH per 100 c. c. sol. per 100 c. c.
P I	13.80	M I	13.50
P II	13.60	M II	11.20
P III	13.80	M III	13.00
P IV	13.80	M IV	13.90
R I	14.00	I I	13.50
R II	13.50	I II	13.00
R III	13.00	I III	13.60
R IV	13.90	I IV	13.20

For the sake of comparison, averages of the several determinations, made by each method, are given in Table VI.

TABLE VII.

Average of	Corallin Method.	Litmus method.	Conductivity method.
P series	13.32	14.92	13.75
R series	12.98	15.50	13.60
M series	16.00	13.81	13.65
I series	15.32	15.51	13.32
Average of all series	14.41	14.95	13.58
Maximum variation	3.02	1.70	0.43
Maximum variation above (+) and below (−) average	+1.59	+0.59	+0.17
	−1.43	−1.11	−0.26

The determinations by the corallin and litmus methods were made on the same solution but the determinations by the conductivity method were made upon a solution of slightly different strength. The advantages of the conductivity method over the other two is well illustrated in the above table. The results by the corallin and litmus methods are very variable, the greatest variation in the first case being 3.02 while in the second case it is 1.70.

The results by the conductivity method are very much closer, the maximum variation in the averages being only 0.43. If we assume the average of all the series to be the true result, then the maximum

variation below the average is only 0.26 and the maximum variation above the average is 0.17.

These differences might well be considered within experimental error.

Ratio of Ammonia to Citric Acid.

Dr. McCandless, the referee on phosphoric acid for the Association of Official Agricultural Chemists in 1909 suggested a reagent be used which should have the same ratio of ammonia to citric acid as the pure triammonium salt. This ratio is 1:3.765. He made some cooperative tests with three other chemists, in which solutions were obtained having ratios from 1:3.775 to 1:4.189. Some time later the division of Fertilizer Chemists of the American Chemical Society recommended a solution in which the ratio of ammonia to citric acid was 1:4.25. A neutral solution was made up by the conductivity method and the ratio of ammonia to citric acid determined. An average of three determinations gave a ratio of 1:3.785. This would probably have approached still closer to the theoretical ratio if the neutral solution had been made up immediately after making the conductivity measurements. During the several days that elapsed between the determinations of the quantity of dilute ammonium hydroxide solution required to give perfect neutrality and the actual preparation of the neutral solution, the strength of the dilute ammonium hydroxide solution was probably changed. It seems probable that this method could be used to give more satisfactory results than the present official method.

Conclusions.

The present official method for preparing a neutral solution of ammonium citrate is extremely unreliable.

The purified litmus method gives somewhat better results although the limit of error is too great for reliable work.

The conductivity method, on the other hand, is reliable and not difficult of operation and the results obtained by different workers agree very closely.

WHAT IS THE ANTIGEN RESPONSIBLE FOR THE ANTI-BODIES IN DORSET-NILES SERUM?

Technical Bulletin No. 13.

BY WARD GILTNER.

The Dorset-Niles serum is a protective serum against hog cholera. Aside from our knowledge of its protective power, what proof have we that this serum contains anti-bodies? Our researches have shown the presence of agglutinins for B. cholerae suis and protective substances against virulent cultures of this organism. However, it is not considered that B. cholerae suis is the etiologic factor of prime importance in the production of hog cholera. Therefore we should look upon the filterable virus as the antigen possessing greatest importance and we should seek to ascertain the specific anti-bodies resulting from the interaction of the filtered virus and the pigs treated.

In attempting to study the phenomena resulting from the interaction of antigen and the body cells or fluids it is advisable to divest each factor of all complicating elements. We have previously studied the Dorset-Niles serum and its agglutinative action on B. cholerae suis. This serum was from animals that had been treated with large doses of hog cholera virus blood. This virus blood is supposed to contain frequently both B. cholerae suis and the filterable virus, probably two distinct antigens.

In the production of anti-bodies in the blood of a pig these two antigens may exert influences independently, symbiotically or antibiotically. We have attempted to obviate complications by using an antigen composed of B. cholerae suis only or the filterable virus only.

We first attempted to hyperimmunize a pig by the use of normal pig blood and bouillon cultures of B. cholerae suis. The culture used was "virus 136" and has already been described.* The treatment of the pig employed in this experiment was as follows:

Virus pig 139, Duroc-Jersey, wt. 125 lbs. Injected 5 c.c. virus Expt. 199 (supposed to contain both B. cholerae suis and the filterable virus) 12-7-'09, into the muscles of the ham. The pig remained well. Failure to develop hog cholera is attributed to natural immunity since another pig from the same lot injected at the same time with a similar dose of the same virus developed a typical case of hog cholera in 8 days. On 12-22-'09, there was injected into the axillary region, 150 c.c. of defibrinated blood from Expt. pig 237 mixed with 50 c.c. of a 20 hour bouillon culture of B. cholerae suis.

No visible or palpable lesions produced.

On 12-30-'09 there was injected into the opposite axillary region 465

* See Tech. Bul. No. 3 and No. 8, Mich. Agri. Expt. Sta.

c.c defibrinated blood from Expt. pig 323 B mixed with 100 c.c. of a 16 hour bouillon culture of B. cholerae suis.

On 1-4-'10 there was injected 150 c.c. of defibrinated blood from Expt. pig 255 mixed with 150 c.c. of an 18 hour bouillon culture of B. cholerae suis.

Pig thin but vigorous and good appetite; walks with stilted gait. No abscesses visible or palpable.

On 1-12-'10 drew 289 c.c. blood from tail, defibrinated and preserved in .5% phenol.

On 1-13-'10 injected 150 c.c. defibrinated blood from Expt. 193 mixed with 150 c.c. of a 16 hour bouillon culture of B. cholerae suis.

On the afternoon of this day the pig died. The only lesions were local and consisted in an infiltration and necrosis of the muscular and connective tissue between the shoulder and thorax. The tissues were greenish in color, spongy and saturated with a foul-smelling, dirty liquid. The last injection did not appear to have been absorbed.

An account should be given of the pigs furnishing the blood with which the cultures were mixed.

Expt. 237, Yorkshire, wt. 29 lbs. 7-8-'09, received 10 c.c. mixed serum 264 and 1 c.c. virus Expt. 101. Remained well. 12-21-'09 killed; normal.

Expt. 323 B., wt. 36 lbs. Just received. No treatment. 12-28-'09, killed; normal.

Expt. 255, wt. 21 lbs. 7-8-09, received 12.5 c.c. mixed serum 28. 12-3-'10, killed; normal.

Expt. 193, wt. 15 lbs. 4-29-'09, received 15 c.c. mixed serum 17 and 1 c.c. bouillon culture B. cholerae suis, "No. 2 Rabbit 25" in the ear vein. 5-25-'09 injected one agar slant, 24 hours old B. cholerae suis "No. 2, Rabbit 25" in muscles. Produced abscess; opened and disinfected.

6-22-'09 injected 1 c.c. virus 99 in muscles;

7-16-'09 injected 5 c.c. virus 107 in muscles;

1-11-'10 killed; normal.

Our object was to make an artificial virus blood containing a maximum of B. cholerae suis but none of the filterable virus. There is no reason to believe that any of the blood used by us contained the filterable virus.

Virus pig 139 is to be regarded as a pig hyper-immunized to B. cholerae suis. We should expect to find in the blood serum of this pig anti-bodies responsive to the specific antigen, B. cholerae suis but none for the filterable virus (unless there is an intimate biological relation between the two).

Table I gives the results of a few agglutination tests with the blood of this pig. An increase in the agglutinative power from 1-125 to 1-25000 is noted.

We know of no test capable of disclosing to us anti-bodies for the filterable virus except the biological test, using pigs. We accordingly tested the serum, drawn from virus pig 139 against hog cholera virus by injecting small pigs. The virus used was not filtered and may have contained both the filterable virus and B. cholerae suis.

Table II shows that the serum from virus pig 139 possessed considerable potency against hog cholera virus. Small pigs were not protected against 1 c.c. of virus by 10 c.c. or 15 c.c. of this serum but protection

TABLE I

Agglutination tests with blood from virus pig 139 treated with normal pig blood mixed with cultures of B. cholerae suis.

Dilution of serum.				50.		100.		125.		250.		500.		800.		1,000.		2,000.		4,000.		5,000.		10,000.		12,500.		25,000.		30,000.	
Treatment of pig.	Date of treatment.	Date of drawing sample.	Culture used in test.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
No treatment		12-7-09	Virus 122	+	−	−	−	−	−	0	0	0	0																		
5 cc. virus experiment 199	12-7-09																														
150 cc. blood from experiment pig 137 and 50 cc. of 20 hour bouillon culture B. Cholerae Suis	12-22-09																														
465 cc. blood from experiment pig 323b and 100 cc. 16 hour bouillon culture B. Cholerae Suis	12-30-09																														
150 cc. blood from experiment pig 255 and 150 cc. 18 hour boullion culture B. Cholerae Suis	1-4-10																														
Bled from tail 289 cc.	1-12-10	1-12-10	Virus 136									+	+	+	+	+	+	+	+	+	−										
150 cc. blood from experiment pig 193 and 150 cc. 16 hour bouillon culture B. Cholerae Suis	1-13-10																														
Died	1-13-10																					+	−	−	−	−	−			0	0

TABLE II

Testing serum from virus pig 139 against virus 122.

No. of pig.	Weight.	Date treated.	Amount of serum.	Amount of virus.	Date died.	Days lived.	Remarks.
Experiment 365	15 lbs.	1-21-10	10 cc.	1 cc.	1-30-10	9 days.	Generalized hemorrhagic lesions of hog cholera.
Experiment 366	16 lbs.	1-21-10	15 cc.	1 cc.	1-30-10	9 days.	Slight hemorrhagic lesions of hog cholera.
Experiment 367	20 lbs.	1-21-10	20 cc.	1 cc.			Remained well.
Experiment 368	25 lbs.	1-21-10	25 cc.	1 cc.			Remained well.
Virus 149	87 lbs.	1-21-10		5 cc.	*2-1-10	11 days.	Extensive hemorrhagic lesions of hog cholera.

*Pig killed while showing symptoms of hog cholera.

was offered by 20 c.c. and 25 c.c. That the virus used was virulent is shown by the death of Expt. pigs 365 and 366 and by the development of hog cholera in virus pig 149.

Should we conclude that anti-bodies against the filterable virus are produced as a result of using B. cholerae suis for the antigen? The Experiment points strongly to the possibility of using cultures of B. cholerae suis in normal pig blood for hyper-immunizing serum hogs.

Possibly the results of this experiment depended partly upon the blood used in connection with the cultures.

We, accordingly, attempted to hyperimmunize an immune pig with cultures of B. cholerae suis only. For this experiment, we used the same strain employed in the preceding experiment and Expt. pig 315.

Expt. pig 315, Chester white, weight 37 lbs.

On 11-30-'09 injected 25 c.c. mixed serum 41 and 1 c.c. virus 128. Pig remained well.

On 2-1-'10 injected 10 c.c. virus 149. Pig remained well for over three weeks, showing immunity to hog cholera virus.

On 2-24-'10 injected 10 c.c. of a 24 hour bouillon culture of B. cholerae suis into axillary region. Estimates from agar plates indicated about 500 million bacteria per c.c.

No local lesion could be detected on 3-3-'10 when 45 c.c. of a 24 hour bouillon culture of B. cholerae suis was injected into the axillary region.

On 3-11-'10 injected into axillary region 45 c.c of a 24 hour bouillon culture of B. cholerae suis. Platings on agar indicated the presence of from one-half to one billion bacteria per c.c. No visible or palpable lesions locally.

On 3-19-'10 injected 40 c.c. of a 24 hour bouillon culture of B. cholerae suis into the axillary region. Platings indicated the presence of about one billion bacteria per c.c. No very distinct swelling locally but considerable soreness. Bled 180 c.c. from tail, defibrinated and preserved in 5% carbolic acid, 10 c.c. to 90 c.c. of blood.

On 4-2-'10 bled from tail 289 c.c., defibrinated and preserved in carbolic acid.

On 4-27-'10 bled from tail 400 c.c., defibrinated and preserved in carbolic acid. Mixed bleedings of 3-19-'10, 4-2-'10, and 4-27-'10. Labeled, "Mixed Serum Expt. 315."

On 5-20-'10 drew sample from tail for agglutination test.

On 6-8-'10 drew sample from tail for agglutination test. Pig weighed 143 lbs. on 6-24-10.

Killed, 7-1-'10. In good condition.

Autopsy: In each axillary region were extensive abscesses, well defined and encapsulated with no indication of infiltration into the surrounding tissues. Contents of abscesses, a dirty yellowish-brown, thick liquid with foul odor. Inoculations gave B. cholerae suis in pure culture. Other organs, normal. Pieces of spleen, kidney, liver and heart produced no growth in bouillon.

Table III shows the results of agglutination tests with samples of serum from Expt. pig 315 drawn at various times. There is manifestly a great stimulus to the production of agglutinins. The mixed serum used in the biological test (vide Table IV) give a reaction at 1-500,000. We have previously found that all samples of Dorset-Niles serum

TABLE III.

Agglutination tests with blood from experiment pig 315 treated with cultures of B. cholerae suis and culture "virus 136".

Dilution of serum.			25.		50.		100.		125.		250.		500.		1,000.		2,000.		4,000.		5,000.		10,000.		12,500.		25,000.		50,000.		100,000.		125,000.		250,000.		500,000.	
Treatment of pig.	Date of treatment.	Date of drawing sample.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
No treatment		11-30-09	0	0	0	0	0	0	0	0	0	0																										
25 cc. Mixed serum 41; 1 cc. virus 128	11-30-09	1-21-09			+	+	+	+	+	+	—	—	—	—																								
10 cc. virus 149	2-1-10																																					
10 cc. 24 hour bouillon culture B. cholerae suis "Virus 136"	2-24-10	3-3-10			+	+	+	+	+	+	—	—	—																									
45 cc. 24 hour bouillon culture B. cholerae suis "Virus 136"	3-3-10	3-12-10											+	+	+	+	+	+																				
45 cc. 24 hour bouillon culture B. cholerae suis "Virus 136"	3-11-10																																					
Bled 180 cc. from tail	3-19-10	3-19-10											+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		—	—	—	—	—	—
40 cc. 24 hour bouillon culture B. cholerae suis "Virus 136"	4-2-10																																					
Bled 289 cc. from tail	4-2-10	4-2-10											+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	—	—	—	—	—
Bled 300 cc. from tail	4-14-10	4-14-10																											+	—	—	—	—	—	—	—	—	—
Bled 400 cc. from tail	4-27-10	4-27-10																											—	—	—	—	—	—	0	0	0	0
Bled 10 cc. from tail	5-20-10	5-20-10																			+	+	—	—	—	—	—	—	—	—								
Bled 10 cc. from tail	6-8-10	6-8-10																			+	+	+	+	—	—	—	—	0	0								
Mixed sample																													+	—	—	—	—	—	—	—	—	—
Killed	7-1-10	7-1-10																			+	—	+	—	+	—	—	—	—	—								

TABLE IV.

Testing mixed serum experiment 315 against virus 170.

No. of pig.	Weight.	Date treated.	Amount of serum.	Amount of virus.	Date died.	Days lived.	Remarks.
Experiment 395	15 lbs.	4-27-10	10 cc.	1 cc.	5-5-10	8 days	Generalized hemorrhagic lesions of hog cholera.
Experiment 396	15 lbs.	4-27-10	15 cc.	1 cc.	5-5-10	8 days	Generalized hemorrhagic lesions of hog cholera.
Experiment 397	15 lbs.	4-27-10	20 cc.	1 cc.	5-3-10	6 days	Generalized hemorrhagic lesions of hog cholera.
Experiment 398	15 lbs.	4-27-10	....	1 cc.	*5-3-10	6 days	Generalized hemorrhagic lesions of hog cholera.

*Killed in dying condition.

that react at a dilution of 1-50,000 are potent. Here we have a serum produced in a peculiar manner with a high agglutinative power, but with little or no potency.

Table IV give the results of the test for potency of the serum from Expt. pig 315 on small pigs. The serum was tested against a very virulent unfiltered hog cholera virus. We found no indication of any protective power in this serum. Perhaps larger doses might have revealed the presence of protective substances.

We next attempted to eliminate B. cholerae suis from the process of hyperimmunization. Our object was to hyperimmunize a pig with virus blood free from any cultivable organisms. It proved to be a herculean task on account of the slow filtration and frequent presence of cloudiness in our filtrates and especially on account of our mistake in selecting a large pig for the experiment. We planned to dilute with equal parts of sterile .85 per cent NaCl solution the clear serum from defibrinated hog cholera virus blood and filter through both Berkefeld and Chamberland filters. We were then to inject 20 c.c. of this filtrate for each pound of live weight of the pig. It was soon discovered that our facilities for filtering the virus blood could not keep pace with the increase in weight of the pig.

Expt. pig 387, Yorkshire, weight 16 lbs.

Feb. 7, 1910, injected 20 c.c. mixed serum 53 and 1 c.c. virus 125.

June 24, weighed 81 lbs.

August 27, injected 250 c.c. virus Expt. 434 and 250 c.c. virus 205. Both lots were clear blood serum diluted with equal parts of sterile .85 per cent NaCl solution and filtered through Berkefeld, then through Chamberland filters.

Two Berkefeld filters were used for virus Expt. 434 and one new Chamberland candle at air pressure of about 3 Kg. per square centimeter. Incubated 3 days, no growth. Virus 205 put through 3 Berkefeld filters and one Chamberland at 2 to 3 Kg. pressure. Incubated 4 days, no growth.

Sept. 1, injected 75 c.c. virus 208, 125 c.c. virus 209, and 50 c.c. virus 211 diluted and filtered as above. Virus 208 put through one Berkefeld and two Chamberland filters at 3 to 4 Kg. pressure. Incubated 2 days, no growth. Virus 209 put through 3 Berkefeld filters and one Chamberland very slowly. Incubated 5 days, no growth.

Sept. 7, injected 25 c.c. virus 208 and 225 c.c. virus 210. Diluted and filtered as above. Virus 210 put through one Berkefeld and one Chamberland filter at 3 to 4 Kg. pressure. Incubated 7 days, no growth.

Sept. 14, injected 75 c.c. virus 211 and 125 c.c. virus 207. Prepared as above. Virus 211 filtered through 2 Berkefeld and one Chamberland filter very slowly. Virus 207 put through one Berkefeld and one Chamberland filter. Incubated 6 days, no growth.

Sept. 20, injected 100 c.c. virus 207, a portion of above Berkefeld filtrate passed through one Chamberland filter 9-13-'10. Incubated 7 days, no growth. The pig weighed 138 lbs. on this date.

Sept. 28, injected 400 c.c. virus 223. Prepared as above. Filtered through one Berkefeld and one Chamberland. Incubated 6 days, no growth.

Oct. 5, injected 500 c.c. of a mixture of virus Expt. 455 to 459. Prepared as above. Filtered through 3 Berkefeld filters and 5 Chamber-

land candles. One portion clouded, others clear after 2 days incubation.

Oct. 15, injected 70 c.c. virus Expt. 453 to 459. This was one of the portions described above.

Oct. 26, injected 50 c.c. virus 224 and 200 c.c. virus 227. Prepared as above; virus 224 filtered through one Chamberland filter only. Virus 227 filtered through four Chamberland filters. Both samples incubated and remained clear.

Nov. 2, bled from tail enough to make 663 c.c. after defibrinating and adding .5 per cent trikresol. Injected 75 c.c. virus 224 and 225 c.c. virus 229. Prepared as above. Virus 224 was a portion of that described above. Virus 229 filtered through one Berkefeld and 3 Chamberland filters. Used only first filtrate.

Nov. 9, killed. Dressed 122 lbs. Secured 1939 c.c. defibrinated blood preserved in .5 per cent trikresol. All the injections had been made in the axillary region. There was never any swelling or soreness. At autopsy, only a yellowish-brown discoloration of the tissues at point of inoculation was discovered.

The records show that a total of 2820 c.c. of diluted virus was used to hyperimmunize Expt. 387. The pig weighed about 160 lbs. when killed. There was, therefore, used only about 17.5 cc. of diluted virus instead of 20 c.c. per pound live weight.

Samples of both bleedings were tested for agglutinative power against B. cholerae suis. Table V shows results of agglutination tests, with the tail bleeding and last bleeding of Expt. pig 387.

TABLE V.

Agglutination tests with serum from experiment 387 and B. cholerae suis.

Dilution.	Tail bleeding.		Last bleeding.	
	Agglutination.	Sediment.	Agglutination.	Sediment.
1-50	+	+	+	+
1-100	+	+	+	+
1-125	+	+	+	+
1-250	+	+	+	+
1-500	+	+	+	+
1-800	+	+	+	+
1-1600	–	–	–	–
1-2000	–	–	–	–
1-4000	–	–	–	–
1-8000	–	–	–	–

The agglutinative power of this serum is as great as that of nearly two-thirds of the samples of Dorset-Niles serum prepared in the usual way. Unfortunately, we failed to test the agglutinative power of the blood of this pig before making the filtered virus injections. We have previously found that pigs treated by the serum-simultaneous method

as Expt. 387 was treated do not furnish a serum agglutinating at a dilution higher than 1-500. We think we are justified in concluding that the agglutinative power of the blood of Expt. 387 increased from 1-500 to 1-8000 during the injections of filtered virus which contained no organisms capable of producing cloudiness in the diluted filtrate.

Another evidence of the absence of B. cholerae suis in the filtrate lies in the fact that no abscesses were produced as a result of injecting extra large volumes of diluted virus. It is a common experience to find that the injections of unfiltered virus blood produce the so-called B. cholerae suis abscesses or caverns filled with a thick, dirty fluid usually walled off by connective tissue. We must admit our ignorance of the cause of the increase in agglutinative power of the serum from Expt. 387.

The potency of the serum from Expt. 387 was tested on small pigs against both the filtered and unfiltered hog cholera virus. The two bleedings were mixed and termed "Mixed Serum Expt. 387." Table VI shows the tests made with mixed serum Expt. 387 against virus Expt. 536. Table VII shows the tests made against virus Expt. 536 diluted with equal parts of .85% NaCl solution and filtered through a Chamberland filter.

It is seen from a study of these two tables that the serum, drawn from a pig hyperimmunized with filtered virus only, protects against either the filtered or unfiltered virus. However, the protective power against the filtered virus is much greater than against the unfiltered virus. Only the pig receiving 5 c.c. of serum dies of cholera when treated with the unfiltered virus, whereas the pig receiving 20 c.c. of serum together with the unfiltered virus dies of cholera. These experiments tend to show that in filtering hog cholera virus through a Chamberland filter, something is removed that has considerable to do with producing hog cholera. Perhaps the filter has an effect of only weakening the virus by permitting the serum to pass but retaining a proportionately large number of the ultra-microscopic organisms, rather than by keeping back a virulent pathogens of an entirely different species such as B. cholerae suis. While it is hardly worth while to speculate, it may be of interest to note that the suggestion has been made that the filterable virus, incapable itself of growing in vitro, is only a peculiar form of a microscopic organism which is capable of growing in vitro. In this case, of course, filtration would weaken the virus by removing a portion of its active principle.

The experiments recorded in Tables VIII and IX furnish additional evidence for the belief that it is easier to protect against the filtered virus than against the unfiltered hog cholera blood. Table VIII shows that 10 c.c. and 15 c.c. of Mixed Serum 35 furnish complete and enduring protection to small pigs against hog cholera when injected simultaneously with 2 c.c. of the filtrate of virus 136 diluted with equal parts of .85 per cent NaCl solution and passed through a Chamberland filter. The filtrate furnished no growth when incubated. Table IX shows that neither 10 c.c. nor 15 c.c. of Mixed Serum 35 protects against 2 c.c. of virus 136 diluted with equal parts of .85 per cent NaCl solution and not filtered. Virulent cultures of B. cholerae suis were found in pure culture in the blood and organs of virus pig 136.

TABLE VI.

Testing mixed serum experiment 387 against virus experiment 536 diluted and filtered.

No. of pig.	Weight.	Date treated.	Amount of serum.	Amount of diluted virus.	Date died.	Days lived.	Remarks.
Experiment 545	11 lbs.	12-9-10	5 cc.	2 cc.	1-8-11	30 days	Hemorrhagic lesions and ulcers.
Experiment 546	17 lbs.	12-9-10	10 cc.	2 cc.	....	....	Remained well.
Experiment 547	16 lbs.	12-9-10	15 cc.	2 cc.	2-8-11	61 days	No cholera lesions. Emaciated, ascarides and lice.
Experiment 548	18 lbs.	12-9-10	20 cc.	2 cc.	3-28-11	109 days	No cholera lesions. Emaciated, ascarides and lice.
Experiment 549	30 lbs.	12-9-10	25 cc.	2 cc.	....	....	Remained well.
Experiment 550	14 lbs.	12-9-10	....	2 cc.	12-18-10	9 days	Acute hemorrhagic cholera.
Experiment 551	13 lbs.	12-9-10	....	2 cc.	12-16-10	8 days	Acute hemorrhagic cholera.

TABLE VII.

Testing mixed serum experiment 387 against virus experiment 536 neither diluted nor filtered.

No. of pig.	Weight.	Date treated.	Amount of serum.	Amount of virus.	Date died.	Days lived.	Remarks.
Experiment 552	9 lbs.	12-9-10	5 cc.	1 cc.	12-12-10	3 days	Liver gorged with blood.
Experiment 553	12 lbs.	12-9-10	10 cc.	1 cc.	12-14-10	5 days	Pleuro-pneumonia and hemorrhages.
Experiment 554	18 lbs.	12-9-10	15 cc.	1 cc.	....	....	Remained well.
Experiment 555	10 lbs.	12-9-10	20 cc.	1 cc.	1-6-11	28 days	Hemorrhagic lesions and ulcers.
Experiment 556	20 lbs.	12-9-10	25 cc.	1 cc.	....	....	Remained well.
Experiment 557	17 lbs.	12-9-10	....	1 cc.	12-16-10	7 days	Hemorrhagic lesions.
Experiment 558	12 lbs.	12-9-10	....	1 cc.	12-15-10	6 days	Hemorrhagic lesions.

TABLE VIII.

Testing mixed serum 35 against virus 136 diluted and filtered.

No. of pig.	Weight.	Date treated.	Amount of serum.	Amount of diluted virus.	Date died.	Days lived.	Remarks.
Experiment 317	50 lbs.	12-15-09	10 cc.	2 cc.	....	....	1-4-10 injected 2 cc. virus 142; 4-26-10 injected 100 cc. virus 172; made Ser. Hog 162.
Experiment 318	50.5 lbs.	12-15-09	15 cc.	2 cc.	....	....	1-4-10 injected 2 cc. virus 142; 4-23-10 injected 100 cc. virus 174; made Ser. Hog 158.
Experiment 319	48.5 lbs.	12-15-09	....	2 cc.	1-19-10	35 days.	1-4-10 injected 2 cc. virus 142; Hemorrhages and ulcers.

TABLE IX.

Testing mixed serum 35 against virus 136 diluted but not filtered.

No. of pig.	Weight.	Date treated.	Amount of serum.	Amount of diluted virus.	Date died.	Days lived.	Remarks.
Experiment 320	44 lbs.	12-15-09	10 cc.	2 cc.	1-15-10	31 days	Hemorrhagic lesions and ulcers.
Experiment 321	41.5 lbs.	12-15-09	15 cc.	2 cc.	12-25-09	10 days	Hemorrhagic lesions extensive.
Experiment 322	53 lbs.	12-15-09	....	2 cc.	12-26-09	9 days	Hemorrhagic lesions extensive.

TABLE X

Testing mixed serum 65 against 1 cc. virus experiment 442.

No. of pig.	Approximate weight.	Date treated.	Amount of serum.	Amount of virus.	Date died.	Days lived.	Remarks.
Experiment 460	20 lbs.	10-4-10	5 cc.	1 cc.	12-6-10	63 days	Hemorrhagic lesions.
Experiment 461	20 lbs.	10-4-10	10 cc.	1 cc.	....	....	Remained well.
Experiment 462	20 lbs.	10-4-10	*3 cc.	*1 cc.	10-26-10	22 days.	Hemorrhagic lesions.
Experiment 463	20 lbs.	10-4-10	*4 cc.	*1 cc.	11-7-10	34 days	Hemorrhagic lesions.
Experiment 464	20 lbs.	10-4-10	*5 cc.	*1 cc.	11-18-10	45 days	Hemorrhagic lesions and ulcers.
Experiment 465	20 lbs.	10-4-10	....	1 cc.	10-41-10	10 days	Hemorrhagic lesions.

*Serum and virus mixed in test tube and incubated at 37° C. for three hours

TABLE XI.

Testing mixed serum 78 against virus experiment 475.

No. of pig.	Approximate weight.	Date treated.	Amount of serum.	Amount of virus.	Date died.	Days lived.	Remarks.
Experiment 523	30 lbs.	10-29-10	5 cc.	1 cc.	11-10-10	12 days	Hemorrhagic lesions.
Experiment 524	30 lbs.	10-29-10	10 cc.	1 cc.	11-10-10	12 days	Hemorrhagic lesions.
Experiment 525	30 lbs.	10-29-10	15 cc.	1 cc.	....	....	Remained well.
Experiment 526	30 lbs.	10-29-10	*3 cc.	*1 cc.	11-10-10	12 days.	Hemorrhagic lesions.
Experiment 527	30 lbs.	10-29-10	*4 cc.	*1 cc.	11-10-10	12 days	Hemorrhagic lesions.
Experiment 528	30 lbs.	10-29-10	*5 cc.	*1 cc.	11-11-10	18 days	Hemorrhagic lesions.

*Serum and virus mixed in test tube and incubated two and one-half hours.

We believe that the title of this paper will permit us to include a few experiments which aimed to determine the effect of the Dorset-Niles serum on hog cholera virus in vitro. We have absolutely no definite knowledge as to the action in vivo of the Dorset-Niles serum. Whether it is antimicrobial, antitoxic, or a promoter of phagocytosis by stimulating the production of opsonins we do not know. It is not easy to determine any of these points. If the serum is antimicrobial, it appears to us that its action on the living cause of hog cholera should take place in a mixture of the two in vitro. If its action is antitoxic, it should at least neutralize any antitoxin produced in vitro. The determination of phagocytosis of an ultravisible organism will require a technic specially devised for the purpose, and probably dissimilar to any with which we are now familiar.

We have worked upon the hypothesis that if a given amount of serum is required to protect a pig against a given amount of virus when they are injected into the pig simultaneously then a less amount of serum will be required to protect against the same amount of virus if the two are mixed in vitro and allowed to remain several hours before injecting into the system of the pig. If a less amount is required then there is evidence of antimicrobial or antitoxic action, probably the former, but if an equal amount of serum is required, then there is no evidence of such action.

Table X shows that 10 c.c. of Mixed Serum 65 protects against 1 c.c. of virus Expt. 442, but that 5 c.c. does not, either when used in the simultaneous method or after mixing with virus and incubating three hours. As a matter of fact, death occurs eighteen days sooner when the mixture is used than when the serum and virus are used separately.

Table XI is not very instructive in this connection, since the disparity is great between the amount of serum that is necessary to protect in the simultaneous method and the maximum amount that was used in the in vitro tests. It is seen that 15 c.c. is necessary to protect by the ordinary method, while we used only 5 c.c. in the mixture after incubating two and one-half hours. We have not proved that there is no in vitro action, since our work is too limited in character, but our results indicate that it is doubtful whether this line of experimentation will be fruitful of results.

SUMMARY.

1. Three pigs were hyperimmunized by injections of (a) B. cholerae suis mixed with pig blood free of the filterable virus, (b) pure cultures of B. cholerae suis, and (c) the filtered virus free of B. cholerae suis respectively.

2. The serum from the pig hyperimmunized with B. cholerae suis mixed with blood protected a 20 lb. pig in 20 c.c. dose and a 25 lb. pig in 25 c.c. dose. This serum also agglutinated B. cholerae suis at a dilution of 1-12,500.

3. The serum from the pig hyperimmunized with pure cultures of B. cholerae suis furnished no protection to a 15 lb. pig in doses of 20 c.c. This serum agglutinated B. cholerae suis when diluted 1-500,000.

4. The pig hyperimmunized with the filtered virus free of B. cholerae suis furnished a serum capable of protecting a 17 lb. pig in 10 c.c. dose

against the filtered virus and an 18 lb. pig in 15 c.c. dose against the unfiltered virus. This serum also agglutinated B. cholerae suis when diluted 1-8,000.

5. It was found that the Dorset-Niles serum is more potent against the filtered virus than against the unfiltered virus.

6. The mixing of the Dorset-Niles serum and hog cholera virus in vitro and incubating 2½ to 3 hours does not seem to lessen the virulence of the virus. There is no indication that mixing the serum and virus in vitro has any advantage over the serum-simultaneous method of injecting these agents for immunizing pigs against hog cholera.

INFECTIOUS ABORTION AND STERILITY IN CATTLE.

Technical Bulletin No. 14.

BY WARD GILTNER.

The economic importance of these affections, if they be distinct affections, or of these manifestations resulting from whatever etiologic factor, is becoming more apparent each year. The effect on the breeder of valuable registered cattle resulting from abortion and subsequent failure to breed in his stock is significant in that there is a possibility of the withdrawal from the ranks of breeders of some men whose services are invaluable to the great work of live stock improvement. The condition is the more serious because of the fact that scientific research has been so little directed toward overcoming these troubles.

We have arrived at the point where many bacteriologists are confident that the cause of infectious abortion is Bact. abortus (Bang). The cause of granular vaginitis and sterility is not determined bacteriologically although Ostertag at one time was of the opinion that he had a streptococcus as the etiologic factor for the former trouble. Many cases of sterility, either temporary (though often protracted) failure to breed, or permanent sterility are easily attributable to the effects of secondary infection by ubiquitous pus-producing organisms that invade the uterus after an abortion produced by the Bang bacterium. Other cases have no apparent relation to an abortion, although in these cases it is not proven that the Bang organism is absent.

Williams (vide Veterinary Obstetrics) is of the opinion that these cases of granular vaginitis and sterility are best treated by daily vaginal douches with weak (.75 per cent) lysol or bacterol solutions persisted in for six months if necessary. In addition he advocates the manipulations of the ovaries per rectum in cases showing cystic condition or persistent corpus luteum. The presence of the corpus luteum during the first stages of pregnancy, at least, appears to be essential to proper development of the foetus, but its persistence, especially when it becomes cystic, after parturition seems to prevent conception.

Two years ago, we began the use of liquid cultures of lactic organisms (ordinary lactic at first, later Bact. bulgaricum) in these cases as a substitute for chemical or coal tar disinfectants. We have used for these cultures ordinary lactose bouillon, sterile whey, and the acid whey from milk curdled by the lactic organism in pure culture. The last mentioned method is the simplest and is now being used in a number of dairies reporting considerable trouble. In one case, recorded in the 1911 report of the department, at Howell about 50 per cent of the cases thus treated conceived after only a few treatments. It is too early to pass judgment on the efficacy of this treatment in this connection,

but we are confident that it is a valuable measure worthy of trial pending a fuller understanding of the nature of the conditions involved. Our experience with this treatment warrants us in recommending it as superior to other methods of treatment in all cases of retained placenta and following all abortions. Work for two years on the bacterial flora of the vagina by Mr. Knopf and Mr. Himmelberger does not indicate that the lactic organism establishes itself in the vaginal mucosa and that an undue acidity of the mucous membrane is not produced. We hope to continue this investigation of the bacterial flora under various conditions. We are making a report on our work with the abortion organism although it is incomplete and inconclusive in many respects. We have used three cultures that have the characteristics of the Bang organism, viz. (1) "Goda" isolated by us May 1st, 1911 from cotyledon of placenta from Guernsey cow. Both foetus and placenta were removed and cultures made immediately on serum-agar-gelatine. Three out of five tubes gave typical pure cultures; (2) "MacNeal" sent by Dr. MacNeal from Illinois, and (3) "Good" from Prof. Good of Kentucky.

In general, it may be said that growth with these organisms, especially with "Goda," is not vigorous until after many transfers in vitro. We wished to obtain the most suitable medium for mass cultures. During this attempt, we made use of the pregnant uterine wall, the foetal membranes, the foetus and the amniotic fluid separately. In case of the three substances first mentioned, liquid and solid media were made as is usual with fresh chopped meat. The reaction was not corrected in any case and was found to be rather acid in case of uterine wall. None of the media made in this manner was more successful than the usual serum-agar-gelatin, that from the uterine wall was useless possibly on account of acidity. The amniotic fluid was used as a substitute for bouillon after filtering and sterilizing by discontinuous method without correcting reaction or addition of any nutrients. Addition of 1.5 per cent agar made a very satisfactory solid medium. The amniotic fluid media gave better results than any media yet tried. The reaction was neutral or slightly alkaline.

The following experiments with virgin heifers were conducted as preliminary efforts toward the production of immunity by the use of living cultures of Bact. abortus injected subcutaneously. We adopted this method assuming both that the subcutaneous injection would result in stimulating the production of suitable antibodies antagonistic to future invading organisms of the same species and also that the organisms would disappear from the system without contaminating the environment.

May 1, 1911, inoculated with "MacNeal" culture flasks containing 30 c.c. of 5 per cent glycerine bouillon + 10 c.c. of naturally sterile horse serum. Flasks sealed with paraffin, clouded in about four days and increased in cloudiness after which sediment formed. Usually, after a month the plug is drawn into the neck of the flask, sometimes entirely within.

Two virgin Jersey heifers were received June 3, 1911. One is referred to as Light, the other Dark. Their previous history not known.

June 8, drew blood from jugular of each. Mucosa of vulva of Dark was smooth and pink, that of Light was congested and very rough with papules.

Blood samples drawn on this date gave following agglutinative results. A six-day-old culture of Bact. abortus in glycerine bouillon was used. Examination made after 48 hours.

Light.	1-10—complete.	
	1-20—sediment considerable, slightly cloudy.	
	1-50—sediment slight, cloudy.	
	Check—no change.	
Dark.	1-10—complete.	
	1-20—complete.	
	1-50—sediment considerable, slightly cloudy.	
	Check—no change.	

On this same day Light was injected subcutaneously behind the shoulder with 65 c.c. of culture described above. The following temperature records show the effect of this injection which was made at 2 p. m.:

6- 8-11.—	4 p. m.	101.4
	5 p. m.	101.5
	6 p. m.	101.5
6- 9-11.—	7 a. m.	102.5
	8 a. m.	102.6
	9 a. m.	104
	11 a. m.	103.5
	1 p. m.	103.8
	4 p. m.	104.1
	7 p. m.	104
6-10-11.—	7 a. m.	104
	12 m.	103.5
	4 p. m.	103
6-11-11.—	7 a. m.	102.8
	12 m.	102.6
	4 p. m.	102.5.
6-12-11.—	7 a. m.	102.7
	12 m.	102.5
	4 p. m.	102.2
6-13-11.—	7 a. m.	102.3.
	12 m.	102.5
	4 p. m.	102.5
6-14-11.—	7 a. m.	101
	12 m.	101
	4 p. m.	101.6
6-15-11.—	7 a. m.	101

June 15, drew blood from jugular of each heifer. Light showed local swelling at point of inoculation, hard and painless.

Agglutination tests with samples of blood drawn on this day gave following results:

Light.	1- 50—complete.	
	1-100—complete.	
	1-250—complete.	
	1-500—sediment considerable, quite cloudy.	
Dark.	1-10—complete.	
	1-20—nearly complete, very slightly cloudy.	
	1-50—sediment considerable, cloudy.	
	Check—no change.	

It will be seen from the agglutination tests that the agglutinative power of the blood serum of the treated animal, Light, increased by seven days after the injection of the first portion of living abortion germs from 1-10 to 1-250, whereas the blood of the untreated heifer, Dark, showed practically no change in agglutinative power. It is now a well established fact that the agglutinative power of the blood serum of animals affected with infectious abortion is increased. M'Fadyean and Stockman originally demonstrated this in their work of vital importance for the Committee of the British Board of Agriculture and Fisheries in 1909.[1] Later they bring a maturer judgment to criticize this test favorably. In short, they state that "one will be justified in regarding complete agglutination with a serum dilution of 1-50 or 1-100 as strong evidence of infection. The blood serum of animals affected with contagious abortion may agglutinate abortion bacilli in dilutions of 1-800. As a rule, normal serum agglutinates at a dilution of not more than 1-10.[2] Brüll[3] states that sound animals furnish a serum agglutinating at 1-32, while habitual aborters furnish serum agglutinating at 1-120 up to 1-1,600. The permanent value of this test must be furnished by its extensive and critical use under varied conditions.

On this same date, June 15, at 2 p. m., Light was injected as upon the previous occasion with 130 c.c. of culture "MacNeal" one month old, grown in the manner described above. The following temperature records were made:

6-15-11.—	6 p. m.	104
6-16-11.—	7 a. m.	103.6
	12 m.	104
	6 p. m.	105
6-17-11.—	7 a. m.	103.2
	12 m.	103
6-17-11.—	6 p. m.	102.5
6-18-11.—	7 a. m.	102.2
	12 m.	102
	6 p. m.	101.8
6-19-11.—	7 a. m.	101.4

It will be seen that the temperature reaction from the first injection began about 17 hours after the injection, reached its maximum 26 hours after the injection and resumed the normal condition only after five and one-half days although it remained at an elevation of 103 or above for only two days. After the second injection, the temperature was found considerably elevated four hours after the injection, reaching its maximum 28 hours after and resuming the normal condition three days after the injection.

Similar experiments by M'Fadyean and Stockman[1] showed a temperature reaction up to 105° lasting three days in one case, and in the other a reaction up to 106.4° lasting seven days.

The heifers were bred as follows: Dark, June 27, 1911; Light, June 29, 1911, to King Bowser, the college Jersey bull.

Both heifers were brought in from pasture November 7, after an uneventful summer.

November 8, drew sample of blood from jugular of each. Agglutination tests with these samples gave the following results:

Light—1-10 to 1-250 complete.
Dark—1-10 to 1- 50 complete.

On the same day there was injected intravenously into each heifer 10 c.c. of culture of "MacNeal" in heated horse serum + glucose glycerine bouillon 5 days old.

The following temperature records were made:

	Light.	Dark.
Nov. 8—night	101.5	101.4
Nov. 9—morning	101.1	101.3
noon	102.1	101.7
night	102.8	102.5
Nov. 10—morning	102.2	102.5
noon	100.2	101.4
night	102.2	102.5
Nov. 11—morning	102.5	101.8
noon	103	102
night	103.5	102.5
Nov. 13—morning	101.5	101.1
noon	101.5	101.6
night	101.6	101.9
Nov. 14—morning	101	101.7
noon	101.4	101.5
night	101.5	102.2
Nov. 15—morning	101.1	101
noon	100	101.2
night	101.1	102.7
Nov. 16—morning	101.5	101.2
noon	101.9	102.1

The temperature reaction in these cases was very slight. No other effect of the injection was observed.

On Feb. 16, 1912, injected into jugular of each heifer 10 c.c. of culture "MacNeal" in amniotic fluid 20 days' growth, also injected 30 c.c. into vagina of each. The following temperature records were made:

Feb. 17, Dark, 100.2, Light, 101.2
Feb. 18, Dark, 101.6, Light, 101.2
Feb. 19, Dark, 101.3, Light, 101.4

This treatment produced no apparent results.

Dark calved normally, April 10, 1912.

Light calved normally, April 15, 1912.

No deductions can be drawn from this experiment except it be that injections of living abortion bacilli, unless more virulent than the strain employed by us, may be made either intravenously or subcutaneously with impunity on cattle either pregnant or non-pregnant. It was hoped and expected that Dark would abort thus showing the pathogenic, abortifacient properties of the organism used and that Light would not abort showing an artificial immunity due to the original subcutaneous injections or, if abortion took place, showing the inadequacy of such injections. The organism must be greatly attenuated.

The effect of injections of dead cultures or of the products of the growth of abortion germs may be further seen in the following experiments conducted with a view to test the efficacy of "abortin" as a diagnostic agent.

"Abortin" was first described by M'Fadyean and Stockman[1] who recognized in it only limited possibilities. Brüll[3] reports unfavorably on its use. Our results are reported because they indicate that a reaction takes place in some cases. We cannot come to a conclusion as to the value of this test even after studying our results. The test should be studied a number of years longer to thoroughly test its worth and possibilities. The injection of "abortin" may have some immunizing effects available in preventing an infected animal from aborting. Some of our records indicate this possibility very strongly. This is more significant in view of the fact that many abortions had taken place up to the time of the application of the tests recorded in Table II when all the pregnant animals in the herd were tested. No abortions took place after this test was made, although in one case at least (Molly B) there were suspicious symptoms of abortion between the time of the test and the date of normal calving. It is possible that 21A and 11A1 were also favorably affected by the treatment.

The "abortin" which we used was made by growing Bact. abortus (Goda and MacNeal) in naturally sterile horse serum 10 c.c. + glycerinated bouillon 60 c.c. for 49 days at 37°C. Cloudiness was considerable and sediment abundant. The cultures were heated for 30 minutes in steam and filtered several times through filter paper, consequently contained many dead organisms. The material was preserved in .5 per cent phenol by addition of one part to nine of 5 per cent solution of phenol. The "abortin" used by us is designated "E" made from pure culture of "MacNeal" and "B" and "C" made from culture "Goda." It is not at all improbable that a more powerful reagent can be made capable of giving better results.

Certainly, nothing definite can be concluded from the data recorded here. A study of Table III may throw some light on the value of "abortin" as a diagnostic agent. The first column contains the names of the cows that did not react to the test and calved normally. It is presumed that these animals were not affected with the abortion germ. In the second column are the names of those that reacted, yet calved normally. It is very probable that these animals were affected with the abortion germ yet carried their foetuses to full term as not infrequently happens. They may have been protected by the dose of "abortin" against

the action of the abortion germs. If this may be accepted as the explanation, we have here valuable evidence that a bacterial therapeutic agent for this disease is at least a possibility. The next column shows us those that aborted yet gave no reaction. This should not happen if we expect this test to be valuable. We may be able to explain away the weakness of the test in this connection. Three animals, Colantha Queen 2nd Girl, Colantha Margolyn, and 25B1, failed to react although they had aborted and had reacted to a previous test. Possibly their failure to react to the second test is attributable to the effects of the previous injection of the reagent. This is the case in tuberculin testing many times. In the case of 22A, we see that the test was made over one month after the abortion. Possibly, the effects of the abortion did not remain long after the act, thus leaving the animal not in a position to respond to the reagent. This suggestion, however, will not explain the absence of a reaction in Rebella. We are perfectly willing to admit that all of the possible explanations are very weak. The fourth column gives the reactors that aborted. These are the real tests of the diagnostic agent. Two of these cases, 21A1 and Bonheur Lassie 2nd, may be discarded as of little value on account of their high pre-injection temperatures. In other cases, also, the temperature response was slight. Little significance need be attached to the last column. At least, these animals acted as one would expect.

In connection with the observations on sterility previously made, we call attention to the following observations: On July 1st, 1912, the herdsman reported the following animals probably safely in calf, viz.: Nos. 1, 2, 4, 5, 6, 7, 8, 10, 13, 14, 15, 17, 18, 20, 28, 30; the following were not safely in calf and had been bred repeatedly: Nos. 9, 16, 19, 21, 22, 23, 24, 25, 26, 27, 29, 31, 32, 33. The remaining animals had been either killed or sold. It is of interest to note the large number of failures to breed in those animals listed in Table II. An explanation does not suggest itself to us.

In conclusion, we wish to call attention to the weakness of the "abortin" test as a diagnostic, but hasten to add that it should not be condemned too harshly or rejected until its true worth has been determined. We suggest the advisability of making parallel tests with the agglutination test, complement fixation test and with "abortin." Finally, it is gratifying to note the apparent entire absence of untoward effects resulting from the use of either living cultures of Bact. abortus or sterile filtrate from its growth.

Thanks are due Profs. Anderson and Brown for permitting the use of their herds, also to Mr. Himmelberger for valuable assistance in pursuing these investigations.

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2. The agglutination test in the diagnosis of bovine contagious abortion. Jour. Comp. Path. and Ther., Mar., 1912, pp. 22-38.

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TABLE 1.

Showing initial efforts with "abortin" at five different dates.

Name of cow.	Date of test.	Abortin.	Before injection. 8 a. m.	Injection. 8:15 a. m.	Temperatures after injection. 10 a. m.	12 n.	2 p. m.	4 p. m.	6 p. m.	8 p. m.	10 p. m.	Remarks.
1. 14C	Aug. 26, 1911	E	100.8	10 cc.	101	101	101	101.8	102	101.6	102.4	Calved O. K., Nov. 7, 1911
2. 12B	Aug. 26, 1911	E	101.4	10 cc.	101	101.1	101.5	102.1	102.1	102	101.2	Calved O. K., Oct. 5, 1911.
3. L. K'S Kodora	Aug. 26, 1911	E	101.1	10 cc.	100.8	101.1	100.7	101.6	102.2	101.8	102	Not pregnant; killed.
4. College Belle	Aug. 26, 1911	E	102.4	8 cc.	102	102.8	103.8	104.4	104.2	104.1	103.6	Calved O. K., Aug. 27, 1911.
5. Col. Queen 2nd Girl	Aug. 28, 1911	B	101.9	10 cc.	101.6	102.8	104.5	103.4	103.7	104.4	103.4	Aborted Aug. 27, 1911.
6. Rebella	Aug. 28, 1911	B	101.5	10 cc.	101.2	101.1	101.9	101.4	101.4	101.4	101.2	Aborted Aug. 28, 1911.
7. Lady Belle	Aug. 28, 1911	B	101.8	10 cc.	101.6	....	102.1	103.2	103.6	102.1	102.2	Calved O. K., Sept. 12, 1911.
5. Col. Queen 2nd Girl	Sept. 25, 1911	B	101.6	10 cc.	101.4	101.1	101.6	101.4	101.3	102	102.2	Aborted Aug. 27, 1911.
8. 21A1	Sept. 25, 1911	B	104.2	7 cc.	104.2	104.6	105.2	103.8	103.8	104.4	104.8	Aborted Sept. 21, 1911.
9. Houwtje Margolyn	Oct. 6, 1911	C	101.9	10 cc.	102.1	102.4	102.1	102.5	101.6	101.8	101.5	Calved O. K., Jan. 25, 1912.
10. Colantha Margolyn	Oct. 6, 1911	C	101	10 cc.	102.2	102.6	103	102.4	101.8	101.2	101.4	Aborted Sept. 29, 1911.
11. 25B1	Oct. 6, 1911	C	101.6	10 cc.	101.3	102	104.4	104.5	104.4	103	102.9	Aborted Oct. 4, 1911.
12. Grade Hereford	Oct. 6, 1911	C	102.1	10 cc.	101.9	102	102.3	103.5	103.9	104.3	104.2	Calved O. K., Oct. 11, 1911.
13. 22A	Nov. 11, 1911	Mac Neal	101.3	10 cc.	101	102.6	101	101.3	102.2	101.1	101.1	Aborted Oct. 9, 1911.
11. 25B1	Nov. 11, 1911	Mac Neal	101.2	10 cc.	101.9	102.2	101.6	101.7	102	101.3	102	Aborted Oct. 4, 1911.
10. Colantha Margolyn	Nov. 11, 1911	Mac Neal	102.2	10 cc.	101.6	101.8	102	102.7	102.3	102.6	102.6	Aborted Sept. 29, 1911.
14. Hector's Cackle B	Nov. 11, 1911	Mac Neal	101.4	10 cc.	101.3	101.5	102	102.9	103	103.2	102	Aborted Oct. 31, 1911.
15. 24B1	Nov. 11, 1911	Mac Neal	101.4	10 cc.	101.5	102.1	102.4	102.4	102.1	103.4	102.6	Aborted Nov. 6, 1911.
16. Alis Fair	Nov. 11, 1911	Mac Neal	101.1	10 cc.	101.2	101	102	102.2	102	102.8	101.8	Aborted Oct. 16, 1911.
17. College Belle Canary	Nov. 11, 1911	Mac Neal	101.3	10 cc.	102.8	102.8	102.5	102.6	103.2	102.6	102.6	Aborted Oct. 18, 1911.
18. Colantha Queen 2nd	Nov. 11, 1911	Mac Neal	102	10 cc.	101.6	102	102.2	102.6	102.4	103.7	102.3	Aborted Oct. 25, 1911.
19. Bonheur Lassie 2nd	Nov. 11, 1911	Mac Neal	*103	10 cc.	103.1	103.6	103.3	102	102	102	101.9	Aborted Nov. 25, 1911.
20. College Alice	Nov. 11, 1911	Mac Neal	**103.9	10 cc.	103.2	103.4	103	102.1	102	102.3	102.1	Calved O. K., Feb. 26, 1912.

*Very excitable because of not being turned out with other cows.
**Just been dehorned.

TABLE II.

Showing use of "abortin" on all pregnant cows in herd immediately following a severe outbreak of abortion.

Name of cow.	Before injection, Dec. 17-18, 1911. 1 p. m.	6 p. m.	8 p. m.	6 a. m.	8 a. m.	After injection, Dec. 18, 1911. 8 a. m.	10 a. m.	12 n.	2 p. m.	4 p. m.	6 p. m.	8 p. m.	10 p. m.	Remarks.
21. Houwtje de Kol	102	102.6	102	102.1	102.4	Injected 10 cc. Abortin, Mac Neal.	101.5	101.1	102.6	102.5	102.3	102.3	102.1	Calved O. K., Jan. 8, 1912.
22. College Colantha Queen 3rd	102.1	102.3	101.9	102.3	102.8		102.3	101.5	101.6	102.2	102	102.5	102.4	Calved O. K., Jan. 2, 1912. Calf died.
23. L. K's Prize	102.1	102	102	102.5	102.1		100	100.2	101.2	101.6	101.9	101.6	101.7	Calved O. K., May 2, 1912.
24. College Queen	102.5	102.3	102.1	102.9	102.6		101.3	102.3	102.2	102	101.8	101.6	101.5	Calved O. K., Jan. 29, 1912.
25. Molly B	102	102.5	102.2	102.5	102.4		101.6	101.6	101.4	102.4	103.2	104.2	105.4	Calved O. K., Jan. 18, 1912. 106.2 at 10:30. Dec. 21, 1911 had mucous discharge.
26. L. K's Zizania	101.5	102.6	102.3	102	101.9		101.2	100.3	100.6	101.8	101.5	101.5	101.3	Calved O. K., April 2, 1912.
27. Crown Queen	101.6	101	101.1	101.9	101.7		101	100.2	100.5	101.4	101.1	101	101.1	Calved O. K., May 13, 1912. Sold.
28. Miss Hopeful	102.8	102.3	102	102.1	102.6		101	101.3	101.4	101.9	102.2	102	103.2	Calved O. K., Jan. 22, 1912.
29. Handy Margolyn	102.4	102.6	102.3	102.5	102.6		101.4	101.6	101.6	102.7	102.4	102.9	102.6	Calved O. K., Jan. 25, 1912.
30. Stella Margolyn	101.2	102.4	102.1	103.3	102.4		102.2	101.7	102	102.8	103.1	102.8	102.4	Calved O. K., Jan. 4, 1912
31. 21A	102.7	103	102.8	102.2	102.6		102.4	102.5	103.2	103.1	103.4	103	102.4	Calved O. K., Dec. 25, 1911.
32. 11M	102.6	102	101.6	102.8	102.2		102.4	101.8	102.7	103.1	103.8	103.8	102.7	Calved O. K., Dec. 24, 1911.
33. 11X1	102.6	102.4	102	102.3	102.1		101.2	101	101.1	101.7	101.8	101.7	101.6	Calved O. K., April 4, 1912.
34. College Kodora	101.8	101.5	101.4	101.5	102		101.4	100.5	101.6	102.1	101	101.2	101.4	Not pregnant; killed.

TABLE III.

Summarizing the results of the several "abortin" tests.

Calved normally. No reaction.	Calved normally. Reaction.	Aborted. No reaction.	Aborted. Reaction.	Not pregnant. No reaction.
14C	College Belle	Rebella	College Queen 2nd Girl	L. K's Kodora.
12B	Lady Belle	College Queen 2nd Girl Second test after 28 days.	21AI(?) Temperature high before injection.	College Kodora.
Houwtje Margolyn	Grade Hereford			
College Alice	Molly B	22A	Colantha Margolyn	
Houwtje de Kol	HAI (?)	25BI	25BI	
College Col. Queen 3rd		Colantha Margolyn Second test after 36 days	Hector's Cackle B	
L. K's Prize			24BI	
College Queen			Alis Fair	
L. K's Zizania			College Belle Canary	
Crown Queen			Colantha Queen 2nd	
Miss Hopeful			Bonheur Lassie 2nd (?) Temperature high before injection	
Handy Margolyn				
Stella Margolyn				
21A				
11X1				

THE INFLUENCE OF CERTAIN ACID-DESTROYING YEASTS UPON LACTIC BACTERIA.

Technical Bulletin No. 15.

BY ZAE NORTHRUP.

During the fall of 1910, a reddening of the soured milk in a supposedly pure culture of *Bact. lactis acidi* was remarked by one of the laboratory assistants. Upon microscopic examination, several types of organisms were found to be present, so plating methods were resorted to for the isolation of this pigment-producing organism; none of the resulting colonies gave a red chromogenesis. In order to preserve this organism for study, transfers were made into plain milk flasks every month or so.

It was noted that each time a transfer was made, the milk first curded, then shortly afterwards the characteristic reddening appeared. Further effort was made to isolate the red organism, and dextrose agar was the medium from which the pigmented colony was finally isolated. The chromogenic organism proved to be a yeast (3). The lactic bacteria by propagation in this mixed culture seemed to retain their vitality over a much longer period of time than a pure culture of active lactic bacteria growing in milk, which soon produce sufficient acid to effect their own destruction.*

The yeast in this mixed culture seemed to be the most prominent organism involved, so a pure culture each of this red yeast and a lactic bacterium was added to a flask of plain milk to see if the same phenomenon would repeat itself in a pure combined culture. The characteristic curding and later reddening of the milk took place and transfers from this flask from month to month gave results similar to those obtained in the original culture, the curding and the time of curding were practically constant with each transfer.

This caused the question to be raised: To what property or properties is this activity of the red yeast due? Two possibilities present themselves, viz., the revitalizing action of the yeast may be caused directly by the intracellular activity of the yeast, again, it may be due to enzymes which may be either intracellular, liberated by disintegration of the cell, or simply excreted enzymes.

The most plausible explanation of the retention of the vitality of the lactic bacteria by growth with this yeast seems to be that it possesses an acid reducing power, a property common to many yeasts. The next possibility although not considered first is by no means subordinate to the preceding, i. e., the possibility of independent enzymic action.

*G. Troili-Petersson (9) observed a similar phenomenon during his studies upon the stereochemistry of fermentation lactic acid. He grew *Bact. lactis acidi* with *Oidium lactis* in milk culture and discovered that the lactic bacteria were still active at the end of 2½ months.

PART I.

DETERMINATION OF THE SIGNIFICANCE OF THE ORGANISMS OTHER THAN LACTIC IN THE ORIGINAL CULTURE.

Expt. I.

Is the Yellow Coccus Existent in the Original Mixed Culture an Important or a Negligible Factor in the Retention of the Activity of the Lactic Bacteria?

In the effort to isolate the red organism from the original mixed culture a yellow coccus was found in addition to the red yeast and the lactic bacterium. This yeast, designated hereafter as LZ, was used in combination with a well known lactic organism, a typical starter bacterium designated as Strain 2, for determining the relative importance of the yellow coccus in the mixed culture. The coccus was isolated in pure culture and transferred to milk and observed from time to time. It produces acid and eventually curds milk producing a tough curd which shrinks rapidly leaving the whey almost clear.

In order to determine its importance in the mixed culture, the following inoculations were made using 1 cc. of a 3 weeks old culture of No. 2, 1 cc. of a 53 day milk culture of the yellow coccus and 1 cc. of a 53 day whey culture of the yeast LZ. Duplicate cultures were made each, of No. 2 plus the yellow coccus, yeast LZ plus the coccus, No. 2 plus the yeast, and the coccus, lactic bacterium and yeast combined. These were titrated frequently and the changes in the milk noted.

The coccus growing alone in whey and in milk gave the following results upon titration.

TABLE I.

Acid Production of Yellow Coccus.

Age of culture, days.	Whey.	Milk.
5	16°	21°
20	19°	37°
28	22°	*40°
36	24°	**32°
45	25°	38°

*Milk curded, whey separated.

**Curd hard, not easily broken up by shaking. Low acidity most probably due to the necessary lack of homogenicity of the ample used in titrating.

TABLE II.

Effect of the Presence of the Yellow Coccus in the Original Culture.

Age of culture.	No. 2 + Coccus.		LZ + Coccus.		No. 2 + LZ.		No. 2 + LZ + Coccus.	
Days.	I.	II.	I.	II.	I.	II.	I.	II.
2	108°	107°	24°	25°	108°	107°	106°	109°
6	133°	131°	30°	27°	134°	136°	139°	136°
*32	134°	128°	39°	40°	141°	138°	140°	135°
*64	137°	134°	58°	71°	137°	122°	120°	122°

*Test cultures made at this time. See Table III.

TABLE III.

Test Cultures from Table II.

Days.	No. 2 + Coccus.	LZ + Coccus.	No. 2 + LZ.	No. 2 + LZ + Coccus.
32	Becoming acid 24 days	Curded 10 days	Curded 24 hours	Curded 24 hours.
64	No change 44 days	Curded eventually	Curded 15 hours	Curded 15 hours.

From Tables II and III, the conclusion may be drawn that the coccus alone does not favor the retention of the vitality of the lactic bacterium nor does it seem to have any influence either on the acid production of the lactic bacteria or upon the time of curding as determined by the test cultures from the mixed cultures of the three organisms in comparison with those of the lactic organism plus the yeast. For these reasons the coccus may be considered a negligible factor in the retention of the vitality of the lactic bacteria.

Expt. II.

Acid Reduction of Yeasts in Pure Culture.

It is a well known fact that a lactic bacterium will continue to live and produce acid within certain limits if the acid is destroyed or neutralized by the addition of alkali in some form. The preservation of the vitality and activity of the lactic bacteria in the mixed culture was therefore attributed to a probable acid-destroying or neutralizing property of this yeast.

In order to determine whether this red yeast was an acid-reducer, it was compared with three other yeasts known to be such, a scum yeast from brine pickles "DR", a butter yeast "SC" and a yeast from whey "DG." The acid reducing power was tested out in pure culture first, by inoculating with the several yeasts, flasks of whey made approximately +30°, +50°, +70° and +90° acid by the addition of N/1 lactic acid. These flasks were sterilized after the addition of the acid. The whey became somewhat turbid when the acid was added but not enough to prevent observation of the growth of the yeast. Each flask of the group of four whey flasks having the approximate acidities of +30°, +50°, +70° and +90° respectively was inoculated with 1 cc. of a broth culture of one of the yeasts. These flasks were titrated from time to time to determine the acidity and the rate of reduction. The following table shows the relative acid reduction of the four yeasts:

TABLE IV.

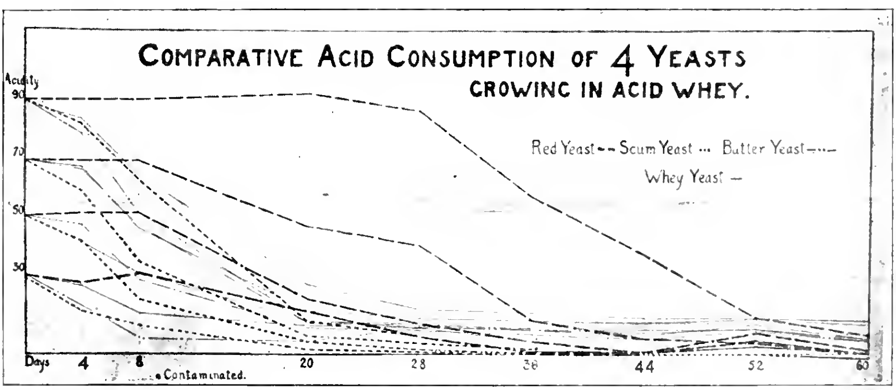
Acid Reduction by Pure Cultures of Yeasts—Demonstrated by Growth in Artificially Acid Whey.

	30°.				50°.				70°.				90°.			
Days.	LZ.	DR.	SC.	DG.	LZ.	DR.	SC.	DG.	LZ.	DR.	SC.	DG.	LZ.	DR.	SC.	DG.
0...	27°	26°	28°	27°	48°	48°	48°	48°	67°	67°	68°	67°	88°	88°	88°	87°
4...	25°	15°	17°	24°	49°	39°	45°	39°	67°	57°	64°	65°	88°	80°	77°	82°
8...	28°	10°	6°	14°	49°	19°	26°	28°	67°	33°	45°	41°	88°	61°	49°	63°
20...	15°	2°	6°	10°	19°	4°	9°	12°	44°	6°	11°	15°	91°	12°	11°	24°
26...	7°	1°	9°	9°	11°	2°	8°	11°	38°	4°	10°	13°	85°	7°	11°	16°
36...	1°	1°	4°	8°	4°	1°	6°	9°	12°	2°	8°	12°	55°	4°	8°	14°
44...	1°	0°	*	7°	1°	1°	5°	*	5°	*	6°	11°	35°	1°	8°	13°
52...	7°	0°	......	8°	4°	3°	7°	......	4°	......	10°	12°	13°	3°	8°	13°
60...	0°	-2°	......	6°	0°	0°	4°	......	0°	......	5°	10°	7°	0°	5°	12°

*Contaminated, titrations discontinued.

From Tables VI, VII, and XI following, it will be noted that a similar acid reduction takes place in the mixed cultures.

In each of the different flasks of the yeast LZ no signs of growth were noted until after the 4th day and none in the flask of +90° whey until after 20 days. The following curve illustrates the comparative acid reduction of the different yeasts. This curve is constructed from the data in Table IV.



Curve I.

Yeast DR, the scum yeast from brine pickles, is much more active in reducing acid than any of the other yeasts; yeast SC is second in activity, yeast DG third, while yeast LZ is much the weakest. From these curves it would appear that the function of yeast LZ is not principally that of acid reduction; this seems to be of secondary importance. It will also be noted that in most cases the acid-reducing function of the yeast LZ is evident only after about 8 days, it then continues to act with greater or lesser rapidity as the amount of acid present in the medium is large or small. The time of the beginning of acid reduction in the pure culture of yeast LZ corresponds quite exactly with the period in the life of ordinary lactic organisms at which the bacterial

cells are beginning to die off. This fact seems, partially at least, to account for the extending of the life and activity of the lactic bacteria in mixed culture, the yeast by its acid-reducing power removing sufficient acid so that a certain percentage, if not all, of the lactic microörganisms may continue to retain their optimum fermenting power.

The acid-reducing power of the yeast LZ was tested in a slightly different way with comparable results. It was grown with 44 day old pure cultures (milk) of the following different lactic organisms, Strain 4, a weak lactic bacterium, No. 3Cb, an organism similar to No. 4, *Bact. bulgaricum* isolated from yoghourt and No. 53B2, a high-acid-producing organism. These pure cultures were titrated, then inoculated with a loopful of a comparatively fresh culture of yeast LZ. The first two lactic bacteria named were not alive, due to the long sojourn in their own products. Within 6 days, the yeast LZ appeared in the flask containing No. 3Cb, the presence of the yeast being ascertained by the appearance of the red color; 2 days later, the yeast appeared in Strain 4, and 12 days after inoculating the milk, a good growth was present in Nos. 4 and 3Cb, while no growth whatever was apparent to the naked eye in the flasks containing the high-acid lactic bacteria; at this time, these latter flasks were reinoculated with a loopful of one of the cultures of LZ which had been growing in artificially acid whey, under the supposition that this culture of the yeast had become inured to a higher percentage of acid than the first culture used, but on account of the high acidity of the lactic culture or to the small amount of inoculum, the yeast never grew in these cultures. The following table shows the acidity in the four cultures after the yeast LZ was introduced:

TABLE V.

Acid Reduction by Yeast LZ—Demonstrated by Growth in Milk Acidified through the Agency of Lactic Bacteria.

Age of culture.	No. 3Cb.	No. 4.	*Bact. bulgaricum.*	No. 53B2.
Days.				
0	114°	108°	347°	228°
12	90°	91°	356°	238°
20	68°	57°	356°	233°
29	51°	29°	258°	233°
73	41°	29°	*402°	*269°
90	...	...	410°	...
119	29°	...	...	...

*At this time a larger inoculum of LZ was introduced. No growth of the yeast resulted.

Either the casein in the milk or the products of the lactic organisms derived through the presence of the casein have some stimulating influence upon the yeast LZ. Comparing Tables IV and V, it will be noted that while 20 days elapsed in the LZ culture of +90° whey before any growth whatsoever became apparent, abundant growth occurred within 6 days in the milk which had attained a much higher acidity, viz., +114°, through the action of lactic bacteria.

Expt. III.

Comparison of Acid-Reduction in Mixed Cultures of Four Yeasts and Four Lactic Bacteria in Milk and in Whey.

Each of the yeasts used in the previous experiment was grown with each of four different lactic bacteria, Strain 2, Strain 4, No. 53B2 and *Bact. bulgaricum.* Duplicate cultures were made in milk and in whey. These were titrated over a period of two months, test cultures being made during and after this period to ascertain the activity of the lactic in question.

The following tables give the fluctuations in acidity in the separate and combined cultures in milk and whey. All cultures were kept at room temperature as the activity of the red yeast is greatly checked at 30° — 32°C., and entirely arrested at 37°C.

TABLE VI.

Acidity of Mixed Cultures in Milk.

Age of culture.	Strain 2 +				Strain 4 +				*Bact. bulgaricum* +				No. 53B2 +			
Days.	LZ.	DR.	SC.	DG.	LZ.	DR.	SC.	DG.	LZ.	DR.	SC.	DG.	LZ.	DR.	SC.	DG.
2..	106°	106°	98°	102°	66°	69°	49°	57°	92°	101°	96°	14°	92°	92°	82°	24°
4..	121°	106°	108°	106°	90°	90°	76°	70°	120°	107°	111°	67°	125°	125°	113°	51°
6..	125°	112°	114°	122°	101°	91°	73°	82°	121°	101°	101°	*190°	142°	137°	141°	99°
8..	125°	109°	111°	111°	105°	105°	106°	94°	123°	108°	116°	232°	151°	150°	142°	*123°
10..	125°	105°	111°	124°	116°	108°	113°	98°	126°	115°	111°	255°	161°	161°	150°	142°
12..	125°	103°	106°	115°	124°	92°	128°	95°	127°	126°	127°	255°	163°	171°	156°	132°
°16..	133°	98°	122°	150°	138°	104°	145°	101°	140°	164°	170°	234°	187°	185°	160°	166°
20..	147°	*90°	141°	*164°	169°	104°	166°	103°	167°	178°	193°	274°	203°	189°	161°	173°
24..	166°	108°	162°	174°	180°	108°	172°	114°	200°	166°	200°	206°	220°	190°	160°	176°
28..	171°	86°	150°	155°	161°	94°	155°	101°	196°	135°	178°	102°	218°	189°	146°	158°
32..	†185°	89°	152°	184°	†189°	100°	155°	98°	†220°	68°	155°	78°	†223°	198°	143°	171°
36..	181°	con.	141°	171°	189°	92°	154°	91°	225°	44°	80°	81°	220°	194°	125°	186°
40..	190°	......	148°	181°	213°	94°	148°	103°	232°	36°	69°	64°	230°	193°	72°	166°
44..	202°	......	95°	108°	215°	85°	126°	90°	234°	41°	53°	66°	237°	200°	51°	154°
56..	221°	......	con.	......	231°	25°	91°	96°	con.	37°	38°	69°	254°	172°	23°	69°

*Slimy.
†Reinoculated with 1 cc. of a 16 day culture of yeast LZ because the red color of the yeast had not appeared at this time.
°Test cultures made at this time; also after titrations were no longer carried on.

From this table, it will be noted that the types of the different lactic bacteria are markedly differentiated by the quantity of acid and the rapidity in which it is made. *Bact. bulgaricum* may seem atypical but this strain has been grown at room temperature (21° — 25°C.) for over three years and is therefore quite comparable with No. 53B2, the other high-acid-producing organism. The active acid-reducing property of the yeasts other than the red yeast LZ, is also marked. These characteristics are more graphically illustrated by curves II, III, and IV.

It will be remarked that in every case the lactic bacteria growing with the yeast LZ continue to make acid, even at the end of 56 days. This was attributed to the fact that this yeast apparently did not grow, as no red color had developed at the end of 32 days; microscopical examination confirmed this theory. At this time, the delinquent cultures

were reinoculated with 1 cc. of a 16 day whey culture of the yeast LZ, but the lactic acid at this time was present in such strength that the yeast did not grow and the presence of the acid eventually killed the lactic bacteria. Test cultures made at the end of 64 days from the mixed cultures of the lactic bacteria and the red yeast showed no growth with the exception of No. 53B2 which is capable of retaining its vitality and activity over long periods of time, not seeming to be influenced by the amount of acid produced, therefore the survival of this lactic bacterium could not be attributed to the presence of the yeast or its products.

It will also be noted that the Strains No. 2 and No. 4 in mixed cultures with yeast LZ reached an unusually high acidity for ordinary lactic bacteria; both microscopical examination and plating revealed only ordinary lactic bacteria and the yeast LZ present. In later experiments, weak lactic bacteria were stimulated by growth with the yeast so that they were induced to produce nearly double their usual amount of acid, but this amount was never greater than that produced by pure cultures of typical lactics.

Table VII gives the data for the duplicate mixed cultures in whey.

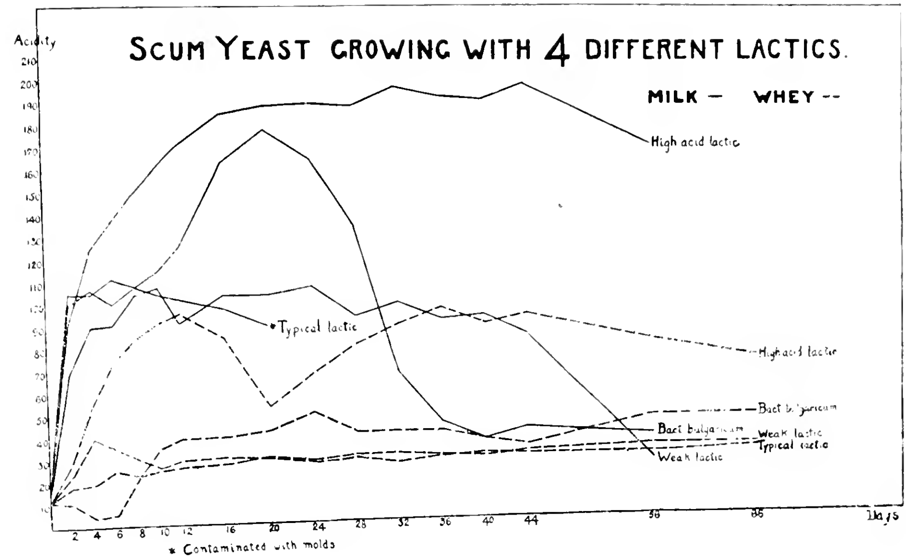
TABLE VII.

Acidity of Mixed Cultures in Whey.

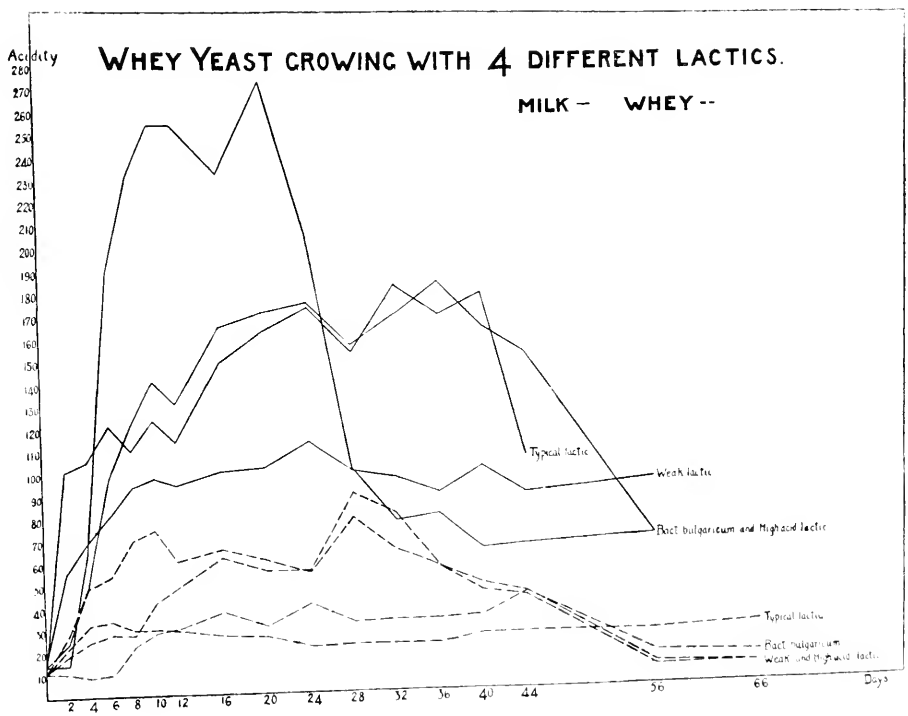
Age of culture.	Strain 2 +				Strain 4 +				*Bact. bulgaricum* +				No. 53B2 +			
Days.	LZ.	DR.	SC.	DG.	LZ.	DR.	SC.	DG.	LZ.	DR.	SC.	DG.	LZ.	DR.	SC.	DG.
2	25°	23°	23°	23°	18°	18°	18°	19°	12°	11°	9°	11°	29°	29°	21°	28°
4	35°	40°	31°	33°	25°	19°	21°	25°	14°	5°	7°	9°	59°	56°	47°	50°
6	35°	36°	30	34°	25°	25°	23°	28°	17°	6	*33°	10°	84°	74°	51°	54°
†8	35	31°	28°	30	23	23°	23°	27°	22°	22°	57°	23°	86°	85°	67°	71°
10	38°	27°	30°	30°	24°	25°	24°	43°	26°	35°	63°	28°	90°	92°	61°	75°
12	46°	29°	38	29°	26°	26°	21°	49°	28°	39°	71°	30°	94°	96°	61°	61°
†16	62°	30°	40	27°	38°	27°	19°	63°	33°	39°	51°	37°	101°	85°	62°	66°
20	89	29°	40°	26°	49°	30°	26°	57°	33°	42°	41°	39°	106°	53°	65°	61°
24	91°	27°	45°	21°	37°	28°	25°	57°	42	50°	48°	40°	108°	68°	70°	56°
28	97°	28	34°	22°	40	30°	25°	91°	33	40°	39°	32°	106°	81°	56°	80°
32	101°	26°	35°	22°	37	30°	25°	82°	33°	40°	33°	33°	108°	90°	55°	64°
36	105	28°	42	22°	34	29	29	57°	34	40°	33°	33°	108°	97°	42°	57°
40	104°	29°	41°	26°	°32	28	26°	48°	35°	36°	14°	34°	109°	90°	11°	46°
44	105°	28°	11	26°	con.	30°	27°	44°	31°	33°	19	44	110°	94°	6°	43°
56	110°	28°	9°	26°	...	32	22°	10°	24	46°	6	15°	110°	82°	7°	9°
66	110°	30°	8°	28°	...	32°	22°	9	51°	46°	6°	14	*122°	74°	5°	9°

*Slimy.
†Test cultures made at this time and at 64 days.
°Yeast LZ not present in these cultures.

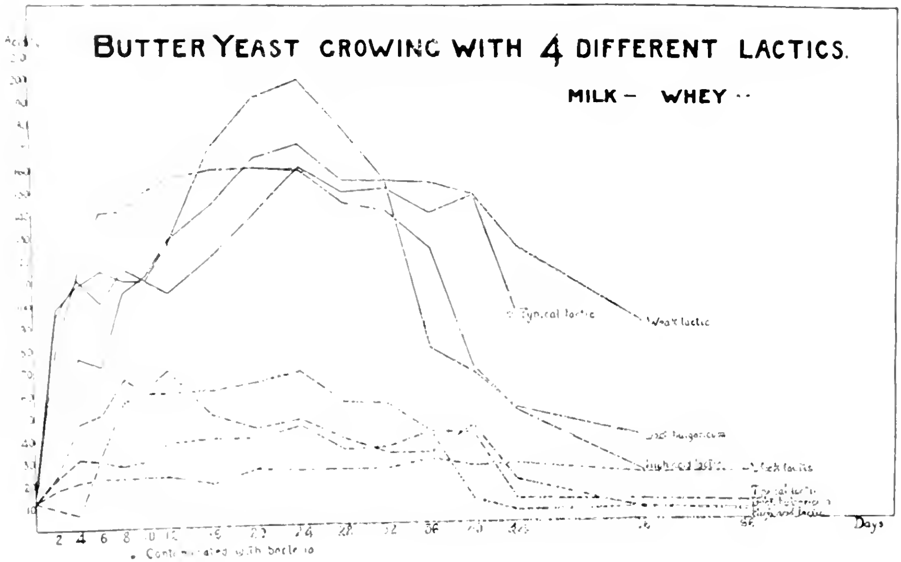
The difference in the four lactic bacteria in mixed culture is much more marked in the whey cultures; the rise in acidity takes place more quickly in No. 2 than in No. 4, and much more quickly in No. 53B2 than in *Bact. bulgaricum* or in the typical starter bacterium. In fact, in the mixed cultures of *Bact. bulgaricum* growing with the three acid-destroying yeasts, the original acidity of the whey (13°) was reduced 4° — 7° by the yeasts before the lactic bacteria had multiplied sufficiently to produce a measurable quantity of acid. Yeast LZ grew only in the whey flask with *Bact. bulgaricum*. The following curves are illustrative of Tables VI and VII:



Curve II.



Curve III.



Curve IV.

The titration records of these mixed cultures in whey and in milk show a gradual rise in acidity, reaching its maximum in from 20 to 30 days, then begins the destruction of the acid. Several of these cultures became contaminated because of the frequency of titrations and these may have influenced the curves in some cases, but a general idea of the action of these yeasts upon the several lactic bacteria in combined culture may be obtained from the above charts.

An effort was made to determine whether the acid produced by the lactic bacteria was merely neutralized in the mixed culture or whether it was decomposed to CO_2 and H_2O by the activity of the yeasts. Quantitative analyses of several of the mixed cultures was made for the determination of the amount of lactic acid present after the acidity had been reduced considerably by the yeast. Because of lack of complete data, the results could only be estimated but they were accurate enough to prove that the acid was destroyed by the yeasts and not simply neutralized.

As checks on the above mixed cultures, pure cultures of each of the lactic bacteria and of the yeasts were made in whey and titrated frequently. These data are found in the following table:

TABLE VIII.

Pure Cultures of Lactic Bacteria and of Yeasts in Whey.

Age of culture.	Yeasts.				Lactic Bacteria.			
Days.	LZ.	DR.	SC.	DG.	Strain 2.	Strain 4.	*Bact. bulgaricum.*	No. 53B2.
1	*4°	6°	5°	7°	7°	7°	4°	8°
3	6°	5°	5°	8°	28°	13°	9°	24°
6	7°	1°	5°	4°	28°	13°	18°	55°
8	9°	7°	6°	5°	31°	13°	22°	69°
10	27°	21°	24°	7°	31°	14°	26°	85°
12	28°	23°	25°	7°	31°	16°	28°	90°
14	24°	15°	22°	18°	31°	30°	25°	93°
16	23°	27°	25°	24°	31°	37°	31°	101°
18	28°	28°	25°	?	31°	con.	27°	101°

*Original acidity of whey + 5°.

Tables IX and X give a summary of the test cultures made from time to time from the mixed cultures in milk and in whey. These cultures were made by transferring a loopful of the mixed culture to a litmus milk tube and incubating at 30°C.

TABLE IX.

Test Cultures from Milk Flasks.

Lactic Bacteria.	Yeast.	15 days.	32 days.	°°64 days.	90 days.	160 days.
Strain 2	LZ	Curded 17 days	Curded 6 days	No change 4 days	No change 3 weeks	No change.
	DR	Curded 24 hours	Curded 3 days	*		
	SC	Curded 24 hours.	Curded 3 days	Curded 2 days	Curded 24 hours	Curded 3 days.
	DG	Curded 24 hours	Curded 3 days	Curded 2 days	Curded 24 hours	Curded 4 days.
Strain 4	LZ	Curded 17 hours.	Curded 3 days	No change 4 days	Curded 7 days	No change.
	DR	Curded 24 hours.	Curded 3 days	Curded 2 days	*	
	SC	Curded 24 hours.	Curded 3 days	Curded 2 days	Curded 24 hours	Curded 4 days.
	DG	Curded 24 hours.	Curded 3 days	Curded 2 days	Curded 2-3 days	Curded 2 days.
Bact. bulgaricum	LZ	Curded 72 hours.	Curded 6 days	Curded 4 days	*	
	DR	Curded 24 hours.	Curded 3 days	Curded 2 days	†Curded 24 hours	No change.
	SC	Curded 24 hours.	Curded 3 days	Curded 2 days	Curded 24 hours	No change.
	DG	Curded 72 hours.	Curded 3 days	Acid, not curded 4 da.	Curded 3 days	No change.
No. 53B2	LZ	Curded 17 days	Curded 6 days	No change 4 days	**Curded 3 days	Acid 3 days.
	DR	Curded 17 days	Curded 3 days	Curded 2 days	Curded 24 hours	Curded 4 days.
	SC	Curded 72 hours.	Curded 3 days	Curded 2 days	Curded 24 hours	Curded 4 days.
	DG	Curded 17 days	Curded 3 days	Acid 4 da. not curded	Curded 3 days	No change.

*Contaminated, discarded.
†Curding caused by contamination with ordinary lactic bacteria; *Bact. bulgaricum* not present.
**Yeast LZ not present. No. 53B2 retains its vitality without the presence of the yeast.
°°At this time plates were made from each test culture for determining the relative activity of the lactic bacteria, time of curding and flavor of curd. (See Table XV).

TABLE X.

Test Cultures from Whey Flasks.

Lactic Bacteria.	Yeast.	8 days.	17 days.	33 days.	66 days.††	90 days.	160 days.
Strain 2 ...	LZ...	Curded 24 hr..	Curded 3 wks	†Curded 4 wks.	**Acid, not curded 6 da	No change 3 wks	No change.
	DR....	Curded 24 hr.	Curded 24 hr.	Curded 3 da...	Curded 3 da.....	Curded 24 hr....	Curded 48 hr.
	SC.....	Curded 24 hr	Curded 24 hr..	Curded 3 da...	Curded 3 da	Curded 3 da.....	Curded 3 da.
	DG....	Curded 24 hr.	Curded 24 hr..	Curded 3 da...	Curded 3 da	Curded 3 da	No change.
Strain 4....	LZ.....	Curded 4 wks.	Curded 24 hr..	Curded 3 da...	*	....	....
	DR....	Curded 24 hr..	Curded 24 hr..	Curded 3 da...	Curded 3 da.....	Curded 48 hr....	Curded 48 hr.
	SC.....	Curded 4 da...	Curded 24 hr..	Curded 3 da...	Curded 3 da.....	Curded 3 da	Curded 3 da.
	DG....	Curded 24 hr..	Curded 24 hr..	Curded 4 wks	?	Slghtly acid 3 da	Curded 48 hr.
Bact. bulgaricum...	LZ	Curded 4 da...	Curded 3 wks.	Curded 4 wks.	Curded 6 da.....	Yeast only......	No change.
	DR....	Curded 24 hr...	Curded 48 hr..	Curded 4 wks.	Acid 6 da litmus reduced......	Yeast only......	No change.
	SC	Curded 24 hr..	Curded 48 hr..	Curded 4 wks.	Curded 3 da.....	Curded 3 da.....	Curded 4 da.
	DG....	Curded 24 hr..	Curded 24 hr..	Curded 3 da...	Curded 3 da.....	Curded 24 hr....	Curded 2 da.
No. 53B2...	LZ	Curded 4 da...	Curded 3 wks.	Curded 4 wks.	Curded 6 da.....	Curded after 3 da	No change.
	DR....	Curded 4 da...	Curded 48 hr..	Curded 4 wks.	Curded 6 da.....	Curded 3 da.....	Curded 3 da.
	SC.....	Curded 4 da...	Curded 48 hr..	Curded 6 wks.	Curded 6 da.....	Curded 3 da	No change.
	DG....	Curded 4 da...	Curded 48 hr..	Curded 4 wks.	Curded 6 da.....	Curded 3 da.....	Curded 4 da.

*Contaminated: discarded.
**Yeast LZ not present, lactic bacteria killed by their own acid except in the case of No. 53B2.
†Cultures marked "Curded 4 wks." in this column curded within 4 weeks or after 3 days, no observations having been taken between those dates.
††Plates were made from each test culture for determining the relative acidity, time of curding and flavor of curd. (See Table XV).

Expt. IV.

Expt. III was repeated, using yeast LZ only, and nine different lactic bacteria including those used in the first experiments; the four additional lactic bacteria were namely, *Streptococcus lacticus*, a typical lactic bacterium isolated from milk from the Emblagaard Dairy, Marquette, Mich., Lactone, a lactic bacterium isolated from a commercial starter in powder form, and Nos. A and B, similar to Strain 4, both isolated from the original mixed culture.

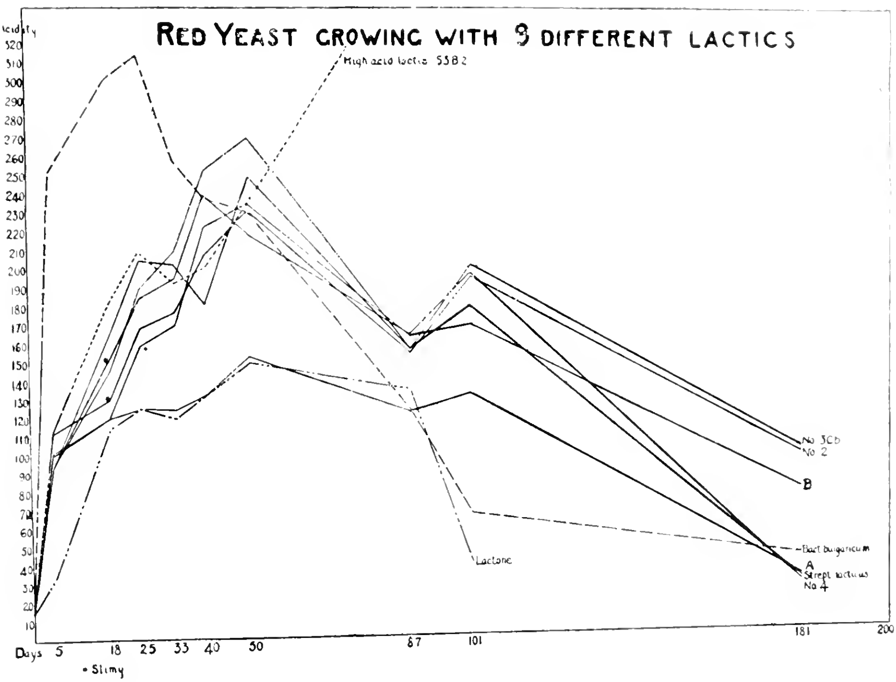
The mixed cultures were made as follows: 1 cc. of a 4 day whey culture of yeast LZ was added to each of 9 flasks containing 250 cc. sterile milk, then to each flask was added 1 cc. of a milk culture of a lactic bacterium; the ages of the different lactic cultures varied, Nos. A and B being 3 days old, *Bact. bulgaricum*, Nos. 53B2 and 3Cb were 4 days old, Strains 2 and 4, 10 days old, *Strept. lacticus*, 7 weeks old and Lactone, 24 days old and not curded. These mixed cultures were incubated as before at 21° — 25°C., titrated and test cultures made. Table XI gives the titrations over a period of 181 days. This table can be compared with Table VI. Curve V following is a graphic representation of this table.

TABLE XI.

Yeast LZ plus Lactic Bacteria in Mixed Culture in Milk.

Days.	Strain 2.	Strain 4.	No. 3Cb.	*Strept. lacticus.*	No. 53B2.	*Bact. bulgaricum.*	Lactone.	No. A.	No. B.
5	112°	93°	93°	93°	*112°	253°	34°	101°	100°
18	**130°	**152°	**146°	*164°	182°	*302°	114°	120°	*120°
25	168°	185°	190°	205°	210°	314°	126°	126°	159°
33	177°	195°	210°	203°	193°	259°	120°	125°	170°
40	208°	240°	253°	182°	201°	239°	133°	133°	223°
50	232°	219°	271°	250°	236°	231°	150°	153°	235°
87	155°	165°	157°	157°	367°	121°	135°	123°	164°
101	196°	198°	203°	180°	***	67°	40°	133°	170°
181	99°	27°	102°	28°	....	42°		30°	79°

*Slimy.
**Slimy, contaminated with a few rod-shaped bacteria.
***Contaminated with molds, lactic bacteria dead, discarded.



Curve V.

In the above table, test cultures were made at the end of 25, 86, and 147 days or about 1, 3, and 5 months respectively with the following results:

TABLE XII.

Test Cultures of Yeast LZ plus Lactic Bacteria.

Lactic Bacteria.	25 days.	86 days.	147 days.
Strain 2	Curded in 24-48 hours	Curded within 24 hours	Curded within 24 hours.
Strain 4	Curded in 24-48 hours	Curded within 24 hours	Curded within 24 hours.
No. 3Cb	Curded in 24-48 hours	Curded within 24 hours	Curded within 24 hours.
Strept. lacticus	Curded in 24-48 hours	Curded within 24 hours	Curded within 24 hours.
No. 53B2	Curded in 2-4 days	Contaminated with mold, lactic dead	....
Bact. bulgaricum	Curded in 4 weeks	Curded within 4 da	Curded in 24-48 hours.
Lactone	Curded in 4 weeks	Curded within 24 hours	Curded within 24 hours.
No. A	Curded within 48 hours	Curded within 24 hours	Curded within 24 hours.
No. B	Curded within 48 hours	Curded within 24 hours	Curded within 24 hours.

From the above, it will be noted that the lactic bacteria were subjected to a process of "rejuvenation" if it may be so called, which was most marked in the case of Lactone, the initial inoculum of which was a litmus-milk culture 24 days old and neither curded nor very acid. This rejuvenating process occurred in another mixed culture of the yeast LZ and Lactone, the data of which is found in the next table.

This culture of Lactone, originally isolated from a dry commercial starter, had been kept in litmus-milk culture in cold storage at 5° — 10°C. for 7 weeks. When taken out, it was but very slightly acid, but curded in 3 days. A transfer from this culture, just curded, and from a culture of the yeast LZ was made into 200 cc. sterile milk, a transfer of Lactone being made into a litmus milk tube for a check.

2 da:—Mixed culture curded; check not curded.
3 da:—Check curded.
5 da:—Yeast LZ becoming evident.

TABLE XIII.

Lactone plus Yeast LZ in Milk.

Mixed Culture.		Test Cultures.	
Days.	Acidity.	Days.	Remarks.
3	105°	64	Curded in 24-48 hours.
5	114°	107	*Curded in 24 hours.
7	121°	167	Curded in 24 hours.
15	110°		
19	106°		
29	113°		
64	132°		
72	130°		
80	71°		
97	63°		

*Plated from test culture and isolated 2 colonies; both curded typically within 24 hours. This pure culture has retained its activity for over three months, in fact is more active than Strain No. 2.

As noted in Tables XI and XIII, Lactone was seemingly rejuvenated so the experiment was repeated to check the results already obtained using as many different cultures of weak lactic bacteria as were available. The ones obtained are as follows: Lactone, a 3 weeks old culture, not acid and not curded; Stock lactic, a bacterium producing almost no acid, does not curd milk but does possess slight litmus-reducing properties; HA, a weak lactic bacterium, curds in 3 days; FC, a less active than HA; and L, a 9 weeks old lactic bacterium which had produced but little acid and had not curded, the culture used in this experiment was the original culture isolated from milk. In each case, 1 cc. of a 14 weeks old whey culture of yeast LZ was used.

TABLE XIV.

Rejuvenation of Weak Lactic Bacteria.

Da.	Lactone + LZ.	Da.	Stock Lactic + LZ.	Da.	HA + LZ.	FC + LZ.	Da.	L + LZ.
3	*Curded............	5	Curded, 48°	1	†Curded....	‡Curded......	3	Curded 47°.
7	........112°	6	.......50°	4	....86°	.....122°	4	......§91°.
9	........113°	16	.... 97°	6	...111°	.....120°	6	...... 95°.
	Contaminated.......		Contaminated.......	16	.††113°	...‡‡127°	16	...§§100°.
				25	...122°	.....112°	25	......108°.

*Test culture not curded in 4 days.
†Test culture curded in 4 days.
††Test culture curded in 24 hours.
‡Test culture curded in 5 days.
‡‡Test culture curded in 48 hours.
§Test culture curded within 12 days.
§§Test culture curded within 24 hours.

The test culture made after L had been growing in mixed culture with yeast LZ for 16 days curded in such a markedly shorter time that plates were made and three pure cultures of the lactic bacterium isolated. These curded within 48 hrs., transfers from these curded within 24 hrs., and continued to retain this activity over a period of a month or more, i. e., up to the time of writing these data.

Expt. V.

Test of Time of Curding and Flavor of Curd of Pure Cultures of Lactic Bacteria reisolated from the Mixed Cultures with Yeasts.

Plates were made from the 64 day old mixed cultures in milk and in whey (see Tables IX and X) and pure cultures of the respective lactic bacteria re-isolated from these plates were transferred to litmus milk; when these cultures were from 5 — 8 days old, 1 cc. of each pure culture was transferred to about 60 cc. of sterile milk and placed at room temperature. Most of these curded within 48 hours, a few took from 4 — 5 days. The score of these milk cultures is found in the following table:

TABLE XV.

Scores of Pure Cultures of Lactic Bacteria after Having Grown for 64 Days in Mixed Culture with Yeasts.

Lactic Bacteria.	Yeast	Scorer No. 1. From mixed cultures in Milk.	Scorer No. 1. From mixed cultures in Whey.	Scorer No. 2. From mixed cultures in Milk.	Scorer No. 2. From mixed cultures in Whey.	Scorer No. 3. From mixed cultures in Milk.	Scorer No. 3. From mixed cultures in Whey.
Strain 2	Pure	Clean acid	....	Quite good	....	High acid	....
	LZ	....	*Sweetish slimy	....	Flat	....	Low acid, same flavor as pure cult.
	DR	....	Clean acid	....	Quite acid, like p. c.	....	High acid, same as p. c.
	SC	Clean acid	Clean acid	Less acid, same as p. c.	Slightly bitter	Same as p. c.	Same as p. c.
	DG	Slightly bitter	Clean acid	Tastes like phenol	Less acid, like p. c.	Peculiar flavor of higher acids	Less acid, like p. c.
Strain 4	Pure	Mild, clean acid	....	Mild, quite flat	....	Better than p. c. of No. 2	....
	LZ	....	....	....	....	....	....
	DR	Very mild, off flavor	Very mild, clean acid	Slightly acid, quite good flavor	Flat	Less acid, like p. c.	Less acid, like p. c.
	SC	Very mild, off flavor	***Not scored	Flat	Not scored	Less acid, like p. c.	Not scored.
	DG	Mild, clean acid	....	Like p. c.	....	Like p. c.	....
No. 53B2	**Pure	Thickened, slimy, very mild acid	....	....	....	....	....
	LZ	....	....	....	....	....	....
	DR	Not slimy, high acid	*Slimy, very mild acid	....	....	....	....
	SC	Not slimy, less acid than above	*Slimy, very mild acid	....	....	....	....
	DG	*Slimy, very mild acid	*No acid, slimy	....	....	....	....
Bact. bulgaricum.	Pure	Very high acid, slimy	....	....	....	....	....
	LZ	*Very mild acid, slimy	....	....	....	....	....
	DR	High acid, not slimy	....	....	....	....	....
	SC	High acid, not slimy	*Sweet, slimy, soft curd	....	....	....	....
	DG	....	Very high acid, not slimy	....	....	....	....

*Soft curd within 4 days.
**Milk thickened, not a typical curd, within 3 days.
***Curdled within 5 days. All the remaining cultures curdled within 48 hours.
The abbreviation **p. c.** signifies pure culture.

Summarizing the above scores, Strain 2 gave a sharp clean acid throughout all the cultures, Strain 4 was mildly acid and both *Bact. bulgaricum* and No. 53B2 produced a very high acid except in the younger cultures. Off-flavors in all cases were found to be due to the specific yeast which had been picked up in the effort to isolate pure cultures from thickly populated plates.

It was noted that the pure cultures of high acid lactic bacteria isolated from their combined cultures with the different yeasts in milk, produced acid faster than the same bacteria from the duplicate cultures in whey. *Bact. bulgaricum* from the mixed culture of *Bact. bulgaricum* with the yeast DG in whey is the exception to this. (See Table XV.) This seems to show that the stimulation produced by the constituents of milk not common to whey is still in effect after the removal of the lactic bacteria from their direct influence.

PART II.

INFLUENCE OF ENZYMES PRODUCED BY YEAST LZ.

The influence that the yeast LZ has upon the different lactic bacteria was attributed to some enzyme or enzymes produced by the yeast. To ascertain whether this influence was exerted by extracellular substances, a whey culture of the red yeast was filtered through a bacteria impervious filter and the action of the filtrate compared with that of the culture itself.

Expt. I.

Determination of Extracellular Substances in the Filtrate of Yeast LZ.

A 4 months' old whey culture of LZ was filtered through a Kitasato pencil filter, obtaining about 50 cc. of filtrate. A flask containing 250 cc. of sterile milk was inoculated with 1 cc. of this filtrate and 1 cc. of a 3 weeks old milk culture of Lactone and another flask of sterile milk inoculated with 1 cc. of Lactone for a check. Both flasks and the filtrate were plated immediately.

As soon as the milk containing the filtrate curded, plates were again made and the acidity recorded from each flask; titrations and platings were made from time to time for over a month. The results are recorded in Table XVI.

The fermenting capacity of the lactic bacteria in this experiment and in those following is calculated according to Dr. Rahn's formula (1) $x = \frac{S \log \frac{b}{a}}{t\,(b - a) \log 2}$, "a" being the initial number of bacteria, "b" being the largest number of cells, "t" the time at which "b" was determined, and "S" the increase in the acidity of the medium, "x" is the number of milligrams of ferment lactic acid produced per hour by a single cell. These calculations were made in the hopes that some additional light would be thrown upon the action of an aggregation of cells of lactic organisms.

TABLE XVI.

Lactone + 1 cc. Filtrate of Yeast LZ.

Age of Culture.	Lactone, check.		Lactone + Filtrate.		Remarks.
	Acid.	Organisms per cc.	Acid.	Organisms per cc.	
Days.					
0	15	105,000	15°	47,800	No growth in filtrate.
4	57	125,000,000	70	204,000,000	Check flask not curded.
6	68°	181,000,000	73°	238,000,000	Check flask not curded.
13	92	286,000,000	86°	271,000,000	Soft curd in check.
26	105	*49,175,000	91°	965,750	Check contaminated.
40	109	*346,000,000	99°	None	....
Fermenting capacity		2.649×10^{-10}	..	13.2×10^{-10}	().

*These counts were most probably influenced by the presence of mold in the check.

The above experiment was duplicated using Stock lactic in place of Lactone. A 1 day milk culture of Stock lactic (not curded) was used in the following experiment:

TABLE XVII.

Stock Lactic + 1 cc. Filtrate of Yeast LZ.

Age of culture. Days.	Stock lactic, check.		Stock lactic + Filtrate.		Remarks.
	Acid.	Organisms per cc.	Acid.	Organisms per cc.	
0	15°	312,000	15°	301,800	No organisms in filtrate.
9	31°	117,000,000	46°	360,000,000	....
11	31°	118,000,000	61°	220,000,000	....
22	34°	33,750,000	75°	61,800,000	....
42	44	30,325,000	90°	220,500	....
Fermenting capacity.		4.814×10^{-10}	......	3.667×10^{-10}	Compared at 9 days.

From Tables XVI and XVII it is evident that the filtrate possesses some stimulating influence upon the lactic organisms, causing both an increase in virility and in acid production and a consequent decrease in numbers.

Expt. II.

Determination of the Nature of the Extracellular Substances present in the Filtrate of Yeast LZ.

To ascertain whether this stimulating influence is due to an enzyme or to peptone formed by the yeast (see Tables XV, XVI, and XVII in Tech. Bul. No. 10) one lot of filtrate was heated for 5 minutes in flowing steam to destroy any enzyme present and the unheated filtrate was kept as control. Lactone was used in this experiment. One cc. of a 26 day culture of Lactone (not curded) was added to each of 3 flasks, to one of these was added 1 cc. of heated filtrate, to the second, 1 cc. of unheated filtrate, leaving the 3rd flask for control.

TABLE XVIII.

Lactone plus Heated and Unheated Filtrate.

Age of culture. Days.	Lactone, check.		Lactone + heated filtrate.		Lactone + unheated filtrate.		Remarks.
	Acid.	Organisms per cc.	Acid.	Organisms per cc.	Acid.	Organisms per cc.	
0	15°	65,800	15°	68,700	15°	97,800	....
5	63°	402,000,000	67°	499,700,000	68°	811,000,000	Soft curd in first two; solid curd in last one.
7	72°	457,000,000	67°	357,000,000	70°	431,000,000	....
12	75°	59,000,000	79°	290,000,000	89°	90,700,000	....
19	84°	12,500,000	87°	35,700,000	86°	33,000,000	....
37	84°	340,000	81°	20,000	89°	30,000	....
Fermenting capacity.	......	11.26×10^{-10}	......	10.01×10^{-10}	......	6.38×10^{-10}	Compared at 72°, 67° and 68 respectively.

The stimulation and subsequent dying off of the lactic bacteria occurs in this experiment also. Strain 4 was used in a duplicate experiment with only slightly different results. One cc. of the filtrate was added to each culture.

TABLE XIX.

Strain No. 4 + Heated and Unheated Filtrate.

Age of culture. Days.	Check.		No. 4 + heated filtrate.		No. 4 + unheated filtrate.		Remarks.
	Acid.	Organisms per cc.	Acid.	Organisms per cc.	Acid.	Organisms per cc.	
0	15°	1,011,000	15°	793,000	15°	*1,615,000	....
2	88°	1,625,000,000	75°	1,718,000,000	79°	1,408,000,000	....
5	110°	1,847,000,000	101°	2,048,000,000	100°	2,302,000,000	....
12	115°	**None	108°	**None	104°	**None	....
22	122°	***None	104°	***None	104°	***None	....
Fermenting capacity.	......	4.179×10^{-10}	......	3.569×10^{-10}	......	2.901×10^{-10}	Compared at 5 days.

*Too large an initial inoculum.
**Dilutions too high to obtain counts, 1-1,000,000, 1-5,000,000 and 1-10,000,000 used.
***Dilutions of 1-100, 1-1000, and 1-10,000 used. Lactic bacteria considered dead.

In Table XVIII, at 5 days the unheated filtrate gave evidence of having stimulated the lactic, and the curd in this flask also of having been formed for a longer time than in the check flask or in that of Lactone plus the heated filtrate. The acid production showed no stimulation by the use of the filtrate either heated or unheated; the optimum virility was reached earlier in the flasks containing the filtrate. The fact that curding was more marked in the unheated filtrate shows that this phenomenon is caused to some extent by an enzyme. The proof of the presence of an enzyme which causes a stimulation of the lactic bacteria is shown more conclusively in Table XX under Expt. III.

Expt. III.

The Effect on the Lactic Organism of Varying the Amounts of Heated and Unheated Filtrate.

In this experiment, different amounts of the filtrate heated and unheated were added to milk cultures of the lactic organism. Seven milk flasks containing 250 cc. milk each were inoculated with 1 cc. of a milk culture of Stock lactic, one of these flasks was reserved for a check and to the others was added respectively 1 cc., 5 cc. and 25 cc. of the heated and unheated filtrate of the yeast LZ. These cultures were plated immediately for the initial counts and as soon as the milk curded in any flask this milk with its duplicate in the heated filtrate and the check also were titrated and plated; each milk culture as it curded was plated with duplicate as above.

The milk culture containing the lactic bacterium plus 25 cc. of unheated filtrate was the first to curd, that containing 5 cc. unheated filtrate next and that containing 1 cc. unheated filtrate last, neither the check culture nor the cultures containing the lactic organism plus the heated filtrate curding at all. The results of this experiment are found in Table XX.

TABLE XX.

The Effect of Varying Quantities of Heated and Unheated Filtrate of the Yeast LZ upon the Functions of Weak Lactic Bacteria.

Age of culture. Days.	Stock lactic.		Stock lactic + 1 cc. filtrate.				Stock lactic + 5 cc. filtrate.				Stock lactic and 25 cc. filtrate.			
	Check.		Heated.		Unheated.		Heated.		Unheated.		Heated.		Unheated.	
	Acid.	Count.	Acid.	Count.	Acid.	Count.	Acid.	Count.	Acid.	Count.	Acid.	Count.	Acid.	Count.
0	19°	176,000	19°	211,500	19°	101,500	19°	305,500	19°	29,100	19°	59,000	19°	27,200
2	22°	64,200,000	......	....	......	....	......	....	......	....	23°	110,000,000	34°	485,000,000
3	22°	59,500,000	......	....	......	....	21°	204,000,000	30°	263,000,000	......	....	......	....
7	29°	122,000,000	34°	224,000,000	32°	160,875,000	......	....	......	....	......	....	......	....
17	40°	365,000,000	44°	398,000,000	54°	172,000,000	41°	135,000,000	73°	194,000,000	......	Contaminated.	88°	167,000,000
29	57°	38,000,000	57°	62,000,000	82°	40,000,000	58°	47,000,000	90°	61,000,000	......	....	95°	8,000,000
39	61°	62,000,000	63°	28,600,000	86°	17,400,000	62°	39,100,000	87°	42,000,000	......	....	95°	30,000?
53	81°	45,950,000	......	Contaminated.	70°	21,100,000	68°	26,080,000	87°	99,000	......	....	96°	100?
Fer. capacity.		*1.398 × 10-10	......	*1.507 × 10-10	......	*4.815 × 10-10	......	**2 283 × 10-10	......	**5 431 × 10-10	......	***7.497 × 10-10	......	***10 31 × 10-10

*Compared at 17 days. Calculated at maximum count.
**Compared at 3 days.
***Compared at 2 days.

At 17 days the Stock lactic check and the cultures growing in the milk containing heated filtrate contained a slight amount of soft curd, perhaps 2 mm. deep in the bottom of the flask.

At this same time the lactic bacteria in the cultures containing 5 cc. and 25 cc. of the heated and unheated filtrate are rapidly on the decrease. This might be attributed to deleterious substances other than acid, formed by the lactic bacteria from certain principles of the filtrate, but a more plausible explanation seems to be that certain constituents of the filtrate stimulate the organisms to produce an abnormally large amount of acid, the excess of which is sufficient to cause a rapid reduction of their numbers. Ordinarily the maximum acidity produced by the Stock lactic in milk culture is about +40°, consequently the acidity of +70° to +90° is sufficient to effect its destruction in a short time.

In Tables XVI, XVII and XIX the disappearance of the lactic organisms cannot be attributed alone to the amount of acid present, as the difference in acidities between the check cultures and those containing the filtrate is but slight, not enough to cause the marked diminution in numbers which occurred.

Expt. IV.

Determination of the Mechanism of the Enzymic Action.

The next question arising was whether this stimulating power of the filtrate was due to enzymic action upon the cell itself or upon the milk constituents by means of which they would be changed into a more available form for weak lactic bacteria. An endeavor to solve this question was made in the following way: 25 cc. of sterile unheated filtrate was introduced in each of 2 flasks containing 250 cc. each of sterile milk and left 48 hrs. at room temperature (see Table XX; 25 cc. unheated filtrate). One flask was then heated in flowing steam for 5 minutes and cooled; both flasks were then inoculated with 1 cc. of a milk culture of Stock lactic, titrated and plated every day or so. The milk containing the filtrate, upon being heated, curded with a marked extrusion of whey, the curd was very tough and hard to break up by shaking. This fact may account for the low initial count in this flask; both flasks should have had directly comparable initial counts as both the amount of milk in the flask and the inoculum were the same in each. These data are tabulated in Table XXI:

TABLE XXI.

Determination of Mechanism of Enzymic Action of Filtrate.

Age of culture, Days.	Milk + 25 cc. unheated filtrate.			
	Unheated.		Heated.	
	Acid.	Bacteria per cc.	Acid.	Bacteria per cc.
0	15°	18,200	15°	3,850
2	42°	493,000,000	34°	415,000,000
4	65°	263,000,000	36°	290,000,000
12	88°	276,167,000	58°	360,000,000
Fermenting capacity at 2 days	....	15.12×10^{-10}	......	14.35×10^{-10}

From these results it may be assumed that the acid-producing function and possibly the fermenting power of the lactic organism is stimulated by the presence of an enzyme in the filtrate. This may or may not be the same enzyme which causes the curding of the milk.

Expt. V.

The Influence of the Addition of Varying Amounts of a Milk Culture of the Yeast LZ to Cultures of the Stock Lactic.

This experiment was carried on for the purpose of comparing the effect of a milk culture of LZ upon the Stock lactic with that of the filtrate of the yeast (Expt. III, Table XX).

A 17 day milk culture of the Stock lactic and a month old culture of LZ were used. To each of 4 flasks containing 250 cc. sterile milk, 0.1 cc. of the Stock lactic culture was added; to 3 of these was added respectively 1 cc., 5 cc. and 25 cc. of the yeast culture. The milk was well shaken up in each case and plated immediately. The plates were kept at 37°C. for 48 hours to prevent the growth of the yeast on the plates and thus allow the lactic bacteria to be counted in pure culture Plates and titrations were made as in Expt. III.

TABLE XXII.

Stimulation of Functions of the Stock Lactic as Influenced by Varying Amounts of a Pure Culture of the Yeast LZ as Inoculum

Days.	Stock lactic, check.		Stock lactic + 1 cc. LZ.		Stock lactic + 5 cc. LZ.		Stock lactic + 25 cc. LZ.	
	Acid.	Count.	Acid.	Count.	Acid.	Count.	Acid.	Count.
0	15°	6,900	15°	5,430	15°	5,970	15°	4,300
1	20°	129,000,000	23°	275,000,000	28°	517,000,000	33°	807,000,000
2	25°	125,000,000	38°	737,000,000	70°	1,145,000,000	87°	1,748,000,000
3	28°	244,000,000	43°	742,000,000	74°	1,415,000,000	102°	1,695,000,000
5	31°	158,000,000	45°	470,000,000	76°	620,000,000	110°	1,240,000,000
11	28°	*1,048,000,000	54°	429,000,000	73°	191,000,000	118°	22,000,000
22	76°	*710,000,000	65°	290,000,000	84°	432,000,000	100°	29,850,000
36	100°	80,000,000	84°	683,000,000	79°	522,000,000	91°	423,000,000
Fermenting capacity	......	**10.06×10^{-10}	......	**8.046×10^{-10}	......	**9.305×10^{-10}	.....	***11.43×10^{-10}

*Abnormally high counts due to contaminating organisms. These were not taken into account in determining the fermenting capacity number.

**Fermenting capacity at 3 days.

***Fermenting capacity at 2 days.

The results in Table XXII show that a very marked difference occurs when greater or lesser quantities of the yeast culture are added to the milk culture of Stock lactic, especially in comparison with the pure culture of the Stock lactic. In the pure culture the count per cc., also the acidity gradually increases while in the lactic culture plus the yeast, the greater the quantity of yeast inoculum, the more rapidly does the acidity and the bacterial count rise and the sooner the number of bacteria per cc. decreases. From the time that the milk cultures were inoculated until the maximum bacterial count was reached the ratio of multiplication runs as follows: Stock lactic : Stock lactic + 1 cc. yeast culture : Stock lactic + 5 cc. yeast culture : Stock lactic + 25 cc. yeast culture = 0.3 : 1 : 2 : 4. This ratio of multiplication was

determined by dividing the maximum number of organisms by the initial number. It will be noted that the greatest diminution in numbers as well as the highest bacterial count occurs in the lactic culture to which was added the largest amount of inoculum of the yeast culture. Similar results have been obtained previously with this same organism and other lactic bacteria. (See Tables XVI, XVII, XVIII, XIX and XX.)

Expt. VI.

Determination of the Length of Time that Weak Lactic Bacteria have to Grow in Association with the Yeast LZ before their Vitality is Restored.

Along with Expt. V was carried on a similar experiment having the following aims, first, to determine how long weak lactic bacteria have to grow in association with the yeast LZ before they become typical, and second, to determine whether any weak lactic organisms may so be rejuvenated.

The plan of this experiment is essentially that of the former. One cubic centimeter of a milk culture of a weak lactic bacterium and 1 cc. of a whey culture of LZ were added to 250 cc. of sterile milk, the flask shaken well to distribute the organisms and plated immediately using dilutions 1-200, 1-500 and 1-1,000. The plates were incubated at 37°C. for 2 days, then counted, giving colonies of the lactic bacterium only. The milk flask containing the yeast plus the lactic organism and also a check flask of the lactic organism were kept at room temperature, 21° — 25°C. As soon as the milk curded in either flask, both the mixed culture and check were plated using dilutions 1-2,000,000, 1-5,000,000 and 1-10,000,000 and the acidity of each recorded. Forty-eight hours after curding, plates were again made using the same dilutions and the acidity recorded as before; these operations were continued about every 8 days afterward.

Each time plates were made a test culture was made, transferring a loopful of the mixed culture to a litmus milk tube and placed at room temperature; the time of curding of this culture was noted and when a test culture curded in a noticeably shorter time it was plated and pure cultures isolated to ascertain whether this characteristic was retained in pure culture, successive transfers being made each day to determine the constancy of the lactic reaction. I am indebted to Mr. L. M. Hutchins for the data in the following tables.

A 5 weeks old culture of Lactone just curded was used in the experiment tabulated in Table XXIII.

TABLE XXIII.

Age of culture. Days.	Lactone, check. Acid.	Lactone, check. Count.	Lactone + 1 cc. LZ. Acid.	Lactone + 1 cc. LZ. Count.	Remarks.
0	15°	....	15°	36,900	Check not plated.
5	62°	603,000,000	70°	437,000,000	....
31	100°	None	120°	903,000,000	....
48	100°	....	133°	....	Not plated.

A 7 days old culture of Lactone, not curded was used in the experiment tabulated below, 0.1 cc. being used as an inoculum.

TABLE XXIV.

Age of culture. Days.	Lactone, check.		Lactone + 1 cc. LZ.		Remarks.
	Acid.	Count.	Acid.	Count.	
0	15°	83,500	15°	54,900	
2	39°	170,000,000	55°		Check only, plated.
6		260,000,000		494,000,000	Acidity not recorded.

In Table XXV, 1 cc. of a 9 day old culture of Stock lactic was used, culture not curded.

TABLE XXV.

Age of culture. Days.	Stock lactic, check.		Stock lactic + 1 cc. LZ.		Remarks.
	Acid.	Count.	Acid.	Count.	
0	15°		15°		Not plated.
7	37°	113,000,000	55°	289,000,000	
9	40°	134,000,000	65°	733,000,000	
31	55°	None	118°	463,000,000	
45	57°		106°		Not plated.

One-tenth of a cubic centimeter of a 16 day old culture of Stock lactic was used in the following experiment.

TABLE XXVI.

Days.	Stock lactic, check.		Stock lactic + 1 cc. LZ.		Remarks.
	Acid.	Count.	Acid.	Count.	
0	15°	6,900	15°	7,170	
2	25°	111,000,000	39°	650,000,000	
3			47°	100,000,000?	Acidity and count of check not recorded.
6		174,000,000		632,000,000	Acidity not recorded.

Although an amount of data has been omitted from the four preceding tables, the general results are directly comparable with those of former experiments. In no case was the rejuvenating influence marked, especially in that of the Stock lactic. This organism is presumably so weak that a much longer association with the yeast LZ is necessary for a restoration of its vitality than in the case of Lactone.

Expt. VII.

Comparison of the Action of Pepsin, of Rennet, and of the Red Yeast upon Weak Lactic Bacteria.

In Expt. IV, it is especially noted that an enzyme is found in the germ-free filtrate of the yeast LZ which is identical in its action upon heated milk with that of rennet; in the mixed culture, a casein-digesting enzyme is also present. As rennin hardly ever exists wholly free from pepsin and this latter enzyme is proteolytic in action, the assumption was made that this latter ferment is a pepsin-like body.

For comparison with the action of these enzymes produced by the yeast, a germ-free filtrate each of commercial rennet extract and pepsin solution was substituted for the filtrate of the yeast.

The rennet used was an extract put up by the Marshall Dairy Laboratory, Madison, Wisconsin, and the label stated that it was preserved by the addition of 1% boric acid. Merck's pepsin, powdered form, was used in the proportion of 1 g. to 100 cc. distilled water for the pepsin solution.

Over 100 cc. of each solution was filtered through a sterilized asbestos Gooch filter into a sterile Bunsen filter flask. This filtrate in each case was bacteria-free. Under sterile precautions each filtrate was transferred in about equal proportions to two sterile flasks, one of these boiled for about 5 minutes over a free flame, the other left unheated.

The experiment tabulated under Table XX was duplicated with the heated and unheated rennet and pepsin filtrates. One-tenth cubic centimeter of a 10 day old culture of Stock lactic (not curded) was used in carrying on these two experiments. In addition to the methods stated in Expt. III, 10 cc. of unheated rennet and pepsin filtrates were each added to a flask of sterile milk, as checks.

TABLE XXVII.

Stock lactic + Germ-free Rennet Extract.

Age of culture. Days.	Check.		Stock lactic + 1 cc. Rennet.				Stock lactic + 5 cc. Rennet.				Stock lactic + 25 cc. Rennet.			
	Stock lactic.		Heated.		Unheated.		Heated.		Unheated.		Heated.		Unheated.	
	Acid.	Count.	Acid.	Count.	Acid.	Count.	Acid.	Count.	Acid.	Count.	Acid.	Count.	Acid.	Count.
0..........	15°	31,200	15°	68,600	15°	86,000	15°	37,000	15°	44,800	15°	31,900	15°	73,500
*1..........	18°	120,000,000	34°	646,000,000	45°	798,000,000	37°	506,000,000	44°	852,000,000	36°	478,000,000	44°	682,000,000
**8..........	25°	69,000,000	76°	380,000,000	94°	458,000,000	78°	458,000,000	93°	681,000,000	74°	610,000,000	96°	619,000,000
Fer. capacity.	......	11.16×10^{-10}	......	14.56×10^{-10}	......	18.58×10^{-10}	......	22.4×10^{-10}	......	18.14×10^{-10}	......	22.85×10^{-10}	......	21.01×10^{-10}

*Fermenting capacity of each determined at 1 day.
**Check flask containing 10 cc. rennet, 16°+ at this time. No change.

Within 24 hours after adding the rennet extract to the sterile milk, the milk in all flasks to which the unheated rennet filtrate had been added showed digestion, the amount corresponding directly to the amount of inoculum. At this time, a slight digestion was also noted in the flasks containing 5 cc. and 1 cc. heated rennet extract and after 8 days the 25 cc. heated rennet extract had begun a decomposition of the casein. The only explanation for the digestion of the milk in the flasks containing the heated rennet solution is that during the boiling over the free flame the coagulated albuminous substance of which there was an abundant precipitate, enclosed the enzyme, protecting it from the destructive action of the heat.

In this table it will be remarked that the varying quantities of germ-free rennet extract added to the milk have no effect, either upon the number of organisms per cc. at the end of 1 and of 8 days or upon the amount of acid formed, i. e., the germ count per cc. of the heated rennet filtrate at the end of 24 hours is 646,000,000, 506,000,000 and 478,000,000 while the corresponding acidities are 34°+, 37°+, and 36°+; of the unheated rennet, 798,000,000, 852,000,000 and 682,000,000 with corresponding acidities of 45°+, 44°+ and 44°. This same relation of acidities is noted at the end of 8 days, the germ count at this time is also comparable. This data is in direct contrast to that obtained from varying the amounts of filtrate (see Tables XX and XXI) or of pepsin solution. (See following table.)

The heated rennet in all cases seems to have a markedly less stimulating effect upon the lactic bacteria both in regard to multiplication and acid production than the unheated rennet. In this respect the results obtained are comparable with those from the experiments with the filtrate and with the pepsin solution. (See Table XXVIII.)

A glance at Table XXVIII will show the striking similarity between the action of the germ-free pepsin solution and that of the filtrate of LZ. (Compare Table XXVIII with Table XX.)

In the foregoing experiments, it would seem that the rennet-like enzyme produced by the yeast LZ is responsible in great part for the stimulation of the reproductive activity and acid production of the lactic bacteria and that the presence of the pepsin-like enzyme retards this stimulating effect as proportionate quantities of it are present. Comparing Tables XXVII and XXVIII, a greater number of organisms and larger quantities of acid are present in the rennet experiment than in that of the pepsin. The results in Table XX are most similar to those in Table XXVIII.

Although the action of the filtrate upon the weak lactic bacterium resembles that of the pepsin solution there is a difference in the appearance of the milk in the two sets of flasks. The milk to which the Stock lactic and unheated pepsin solution were added shows markedly the characteristic peptic digestion while the milk to which the Stock lactic and unheated filtrate were added apparently shows only the shrinking of the curd and extrusion of the whey, it being difficult to determine the presence of a casein-digesting enzyme from the mere physical appearance of the milk.

TABLE XXVIII.

Stock lactic plus Germ-free Pepsin Solution.

Age of culture. Days.	Stock lactic.		Stock lactic + 1 cc. pepsin.				Stock lactic + 5 cc. pepsin.				Stock lactic + 25 cc. pepsin.			
	Check.		Heated.		Unheated.		Heated.		Unheated.		Heated.		Unheated.	
	Acid.	Count.	Acid.	Count.	Acid.	Count.	Acid.	Count.	Acid.	Count.	Acid.	Count.	Acid.	Count.
0..........	15°	112,000	15°	43,800	15°	32,300	15°	59,500	15°	83,000	15°	76,800	15°	71,500
2..........	19°	126,000,000	20°	117,000,000	26°	320,000,000	28°	236,000,000	31°	462,000,000	30°	521,000,000	49°	641,000,000
*5..........	25°	170,000,000	24°	167,000,000	44°	315,000,000	32°	228,000,000	56°	393,000,000	46°	526,000,000	78°	646,000,000
11..........	28°	191,000,000	28°	121,000,000	51°	307,000,000	39°	247,000,000	70°	750,000,000	57°	435,000,000	86°	286,000,000
23..........	46°	13,470,000	53°	45,250,000	92°	156,550,000	65°	490,500,000	94°	96,820,000	......	Contaminated...	102°	6,255,000
Fer. capacity.	......	4.66×10^{-10}	......	4.809×10^{-10}	......	9.15×10^{-10}	......	6.79×10^{-10}	......	9.60×10^{-10}	......	5.632×10^{-10}	......	9.61×10^{-10}

*Fermenting capacity at 5 days.

Table XXIX gives a summary of Tables XVII to XXVIII; the age of culture, acidity and number of organisms which were employed in ascertaining the fermenting capacity of the lactic bacteria in Tables XXIII to XXVI inclusive are omitted as the data therein is incomplete.

TABLE XXIX.

Summary of Tables XVII to XXVIII.

Table.	Culture.	Age of culture.	Acidity at highest count.	Number of organisms per cc.		Hourly fermenting capacity.
				Initial.	Maximum.	
XVII	Stock lactic, check	9 days	31°	342,000	117,000,000	4.81×10^{-10}
	Stock lactic plus filtrate	9 days	46°	301,800	360,000,000	3.66×10^{-10}
XVIII	Lactone, check	7 days	72°	65,800	457,000,000	11.26×10^{-10}
	Lactone plus heated filtrate	5 days	67°	68,700	499,700,000	10.01×10^{-10}
	Lactone plus unheated filtrate	5 days	68°	97,800	811,000,000	6.38×10^{-10}
XIX	Strain No. 4, check	5 days	110°	1,011,000	1,847,000,000	4.18×10^{-10}
	No. 4 plus heated filtrate	5 days	101°	793,000	2,048,000,000	3.57×10^{-10}
	No. 4 plus unheated filtrate	5 days	100°	1,615,000	2,302,000,000	2.90×10^{-10}
XX	Stock lactic, check	17 days	40°	176,000	365,000,000	1.40×10^{-10}
	Stock lactic plus 1 cc. heated filtrate	17 days	44°	211,500	398,000,000	1.50×10^{-10}
	Stock lactic + 1 cc. unheated filtrate	17 days	54°	101,500	172,000,000	4.82×10^{-10}
	Stock lactic + 5 cc. heated filtrate	3 days	24°	305,500	204,000,000	2.28×10^{-10}
	Stock lactic + 5 cc. unheated filtrate	3 days	30°	29,100	263,000,000	5.43×10^{-10}
	Stock lactic + 25 cc. heated filtrate	2 days	23°	59,000	110,000,000	7.41×10^{-10}
	Stock lactic + 25 cc. unheated filtrate	2 days	31°	27,200	485,000,000	10.31×10^{-10}
XII	Stock lactic + 25 cc. unheated filtrate	2 days	42°	18,200	493,000,000	15.12×10^{-10}
	Stock lactic + 25 cc. heated filtrate	2 days	34°	3,850	415,000,000	14.35×10^{-10}
XXII	Stock lactic, check	3 days	28°	6,900	241,000,000	10.06×10^{-10}
	Stock lactic + 1 cc. LZ	3 days	43°	5,430	742,000,000	8.05×10^{-10}
	Stock lactic + 5 cc. LZ	3 days	74°	5,970	1,415,000,000	9.31×10^{-10}
	Stock lactic + 25 cc. LZ	2 days	87°	4,300	1,748,000,000	11.43×10^{-10}
XXVII	Stock lactic, check	1 day	18°	31,200	120,000,000	11.16×10^{-10}
	Stock lactic + 1 cc. heated rennet	1 day	34°	68,600	646,000,000	14.56×10^{-10}
	Stock lactic + 1 cc. unheated rennet	1 day	45°	86,000	798,000,000	18.58×10^{-10}
	Stock lactic + 5 cc. heated rennet	1 day	37°	37,000	506,000,000	22.40×10^{-10}
	Stock lactic + 5 cc. unheated rennet	1 day	44°	44,800	852,000,000	18.14×10^{-10}
	Stock lactic + 25 cc. heated rennet	1 day	36°	31,900	478,000,000	22.85×10^{-10}
	Stock lactic + 25 cc. unheated rennet	1 day	44°	73,500	682,000,000	21.01×10^{-10}
XXVIII	Stock lactic, check	5 days	25°	112,000	170,000,000	4.66×10^{-10}
	Stock lactic + 1 cc. heated pepsin	5 days	24°	43,800	167,000,000	4.81×10^{-10}
	Stock lactic + 1 cc. unheated pepsin	5 days	44°	32,300	315,000,000	9.15×10^{-10}
	Stock lactic + 5 cc. heated pepsin	5 days	32°	50,500	228,000,000	6.79×10^{-10}
	Stock lactic + 5 cc. unheated pepsin	5 days	56°	80,000	393,000,000	9.60×10^{-10}
	Stock lactic + 25 cc. heated pepsin	5 days	46°	76,800	526,000,000	5.63×10^{-10}
	Stock lactic + 25 cc. unheated pepsin	5 days	78°	71,500	646,000,000	9.61×10^{-10}

The fermenting capacity of the pure cultures of Stock lactic varied from 1.40×10^{-10} to 11.16×10^{-10}. The number of days for this bacterium to reach its maximum number of organisms varied from 1 day to 17 days with corresponding acidities of +18° and +40°.

The fermenting capacity of Stock lactic plus 1 cc. of unheated filtrate was 3.66×10^{-10} and 4.82×10^{-10}; plus 1 cc. LZ, 8.05×10^{-10} plus 1 cc. unheated rennet filtrate, 18.58×10^{-10} and plus 1 cc. unheated pepsin filtrate 9.15×10^{-10}. These results being comparable, the unheated rennet extract possesses by far the greatest stimulating power for acid production, while that of the living yeast is comparable with that of the pepsin solution.

Table XXX gives the fermenting capacity of the Stock lactic in pure culture and as influenced by different stimulants. In each case, the number given in each column is followed by the expression "$\times 10^{-10}$."

TABLE XXX.

The Hourly Fermenting Capacity of the Stock Lactic as Influenced by Different Stimulants.

Stimulant.	Lactic, check.	Stock lactic + heated Stimulant.			Stock lactic + unheated Stimulant.		
		1 cc.	5 cc.	25 cc.	1 cc.	5 cc.	25 cc.
Yeast	10.06	....	....	....	8.05	9.31	11.43
Filtrate	1.40	1.50	2.28	7.41	4.82	5.43	10.31
Pepsin	4.66	4.81	6.79	5.63	9.15	9.60	9.61
Rennet	11.16	14.56	22.40	22.85	18.58	18.14	21.01

From the above table, it may be concluded that the fermenting capacity of the Stock lactic is about doubled by the use of 5 cc. or 25 cc. of unheated or heated pepsin or rennet filtrate. This does not appear when the yeast is used nor is the action similar in the presence of the filtrate. This last stimulant seems to have an action peculiar to itself. It will be noted that there is a gradual increase in the fermenting capacity as a greater amount of filtrate is added; this is true in both the heated and in the unheated filtrate, and it will also be noted that the unheated filtrate possesses more stimulating power than the heated as the inoculum is increased. Whether this would be duplicated in a second experiment cannot be stated.

SUMMARY AND CONCLUSIONS.

1. Certain acid-reducing yeasts have the property of retaining the vitality and activity of lactic bacteria over a period of a year or more when grown with them in mixed culture in milk or in whey. In the case of the red yeast, the acid-reducing property does not appear to be its chief function.

2. It is possible that a weak lactic be "rejuvenated," i. e., have its vitality increased by continued association in mixed culture with the yeast LZ, an acid-reducer.

3. This rejuvenating property of the yeasts is due in part to the acid-reducing function, in the case of yeast LZ partially also to rennet and pepsin-like enzymes produced by the yeast.

4. One of these enzymes at least is extracellular in old cultures; the rennet-like enzyme and probably the pepsin-like enzyme were separated from yeast LZ by filtration.

5. Although it was difficult to determine the presence of the pepsin-like enzyme in the filtrate by means of its visible action on the milk, the stimulating action of the filtrate is directly comparable with that of the pure pepsin solution.

6. The pepsin-like enzyme is the one which stimulates the curding function of the lactic bacteria although at first it was suspected that the lactic organisms in some way caused the rennin in the filtrate to act more quickly. This seems to be proved conclusively by the results in Table XXVIII.

7. The question was raised as to whether the enzymes acted upon the milk constituents and thus indirectly upon the lactic bacteria, or whether the influence was immediately upon the lactic bacteria. It

was ascertained that the rennet enzyme in the filtrate acts in part upon the milk constituents (see Table XXI) but the most marked action of the filtrate is upon the lactic bacterium itself; two principles of the filtrate are concerned in this, one destroyed and the other not destroyed by heat. The former is most likely the pepsin-like enzyme or the combined pepsin and rennin and the latter, certain food principles, possibly peptones, produced by the yeast which are not changed by heating.

8. As commercial rennet is never wholly free from pepsin the results in Table XXVII could not be used to refute the immediately preceding statement.

9. The influence of the filtrate upon the virility of the lactic bacterium increases directly as the amount of filtrated inoculum is increased; this is true in the heated as well as in the unheated filtrate.

10. The filtrate both heated and unheated has a marked stimulating effect both upon the virility and upon the acid production of weak lactic bacteria. This results in the rapid dying-out of the lactic bacteria in the cultures to which the yeast filtrate has been added. This dying-out of the lactic organisms may be due to the exhaustion of vital force following the overstimulation caused by the presence of the filtrate. Again, this effect may be attributed to the fact that the organisms have been induced to produce nearly double their usual amount of acid and as a consequence have become hypersusceptible to their own products. This latter theory is in all probability the correct one although the two cannot be distinctly separated. It follows then that a weak lactic bacterium will live much longer in pure culture in milk if no stimulant is added or if acid formation is prevented.

11. The hourly fermenting capacities of the weak lactic bacteria as summarized in Tables XXIX and XXX show that the presence of the yeast filtrate, of the pepsin or of the rennin solution causes an increase of the fermenting power to nearly double that of the check.

12. The yeast used in most of the experiments in this article was the red yeast "LZ" present in the original culture. This was used almost exclusively, for several reasons: the pigment produced renders the presence of this yeast easily discernible to the naked eye; the macroscopic appearance of the mixed cultures of this yeast with lactic bacteria is characteristic; soon after the yeast appears a symmetrical shrinking of the curd occurs, the curd later becomes wholly digested leaving a perfectly clear whey and a plentiful deposit of red yeast cells; this organism does not grow well on ordinary agar and is very susceptible to a temperature very much higher than room temperature; this sensitiveness to high temperatures rendered it possible to plate mixed cultures of LZ and a lactic bacterium and obtain counts of the lactic organism alone, simply by placing these plates at 37°C. for 48 hours.

13. The fact that this red yeast is a strict aerobe and lactic bacteria are facultative, preferably anaerobes, accounts in all probability for one phase of the beneficial associative action.

14. It was proved quite conclusively that the acid introduced artificially or produced naturally in milk or whey is destroyed by the yeasts, not merely neutralized.

15. After sojourning for some time with the different yeasts, the several lactic bacteria were isolated and tested to ascertain whether the flavor of the curd had been changed. These cultures were com-

pared with the original pure culture and no change had been effected.

16. It is noteworthy that the mixed cultures which have become contaminated with molds or other bacteria and yeasts have not lost their power of retaining the vitality of the lactics except in one instance. Foreign organisms seem to have no appreciable effect on the lactic bacterium and the yeast after the symbiosis of the latter had once been established.

17. In the case of the mixed culture of the yeast LZ with different lactic bacteria, the lactic bacterium, even a very weak organism, has a chance to produce its maximum amount of acid before any appreciable acid destruction can take place.

18. The high-acid-producing organism, No. 53B2, unlike *Bact. bulgaricum* and ordinary lactic bacteria, survives a long sojourn at its maximum acidity (in the neighborhood of +280°). The red yeast grows most difficultly with this lactic organism.

19. The red yeast LZ produces several enzymes and other substances which when the yeast is growing in combined culture with a lactic bacterium, stimulate the lactic organisms to greater activity causing the production of a greater number of cells and a larger quantity of acid than would be produced normally in pure culture. This process of stimulation if continued over a period of several months causes a weak lactic to increase its activity until it becomes a typical lactic organism in regard to its power of producing acid, causing litmus reduction and curding milk. The required time for rejuvenating naturally varies with the individuality of the culture, sometimes 3 weeks, sometimes 3 months or longer of symbiotic relationship being necessary to effect the mutation.

20. In order that the lactic bacterium obtain the most possible benefit from the yeast, the yeast itself must be present in the medium with the lactic organism. The several products of each organism appear to attain an equilibrium which is similar to and comparable with that reached in strictly chemical reactions. This equilibrium is happily destructive neither to the lactic nor to the yeast within the periods noted.

21. Many of the above statements are corroborative in their kind, of the conclusions drawn in "Bacterial Associations in the Souring of Milk" by Marshall and Farrand, concerning the associative action of other bacteria with lactic organisms.

22. This phenomenon of associative action in time may solve the problem of keeping other short-lived organisms almost indefinitely without frequent transfers.

Further studies are being undertaken dealing with other phases of this interesting problem.

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THE BACTERIAL ACTIVITY IN SOIL AS A FUNCTION OF GRAIN SIZE AND MOISTURE CONTENT.

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BY OTTO RAHN.

INTRODUCTION.

The discussion concerning the best method for determining the microbial efficiency in soils has entered a new stage since Stevens and Withers* demonstrated by several series of experiments with different types of soils that there is no direct relation between the microbial activity in the soil and in the extract of this soil or in a similar nutrient solution Stevens and Withers are not the first ones to advocate the use of soil rather than liquids for soil bacteria. Practically all work coming from the soil-bacteriological laboratory in Goettingen has been done with soil in its natural condition. But we owe to Stevens and Withers the experimental and conclusive proof that biochemical changes in soil and in solutions inoculated with soil give not the same and not even comparable data. There is no definite relation between the two, and no constant factor will allow of the computation of one datum from the other.

The object of this paper is the study of the physical factors in the soil causing a different development of micro-organisms in soil and solution. Three soil properties can be predicted *a priori* which are probably of noticeable influence:

1. The water content.
2. The actual soil surface giving opportunity for absorption; and
3. The surface of the soil solution giving opportunity for the exchange of gases.

That physical soil properties have a great influence is, of course, known through many experiments. However, the relations have never been studied systematically. For a systematic investigation of the influence of physical soil properties, it is necessary, above all, to exclude chemical influences. This can be accomplished with certainty only if the soil is substituted by an absolutely insoluble material, such as quartz sand. It is further necessary to work with pure cultures, to avoid uncontrollable complications.

While pure cultures and quartz sand have been used by several bacteriologists, this paper varies in one way distinctly from the general

*Stevens and Withers: Studies in Soil Bacteriology.
I. Centralbl. f. Bakt. II Abt. Bd. 23, p. 355.
II. " " Bd. 23, p. 776.
III. " " Bd. 25, p. 64.
IV. " " Bd. 27, p. 169.

procedure in soil bacteriology, because it gives the bacterial development at various time intervals, emphasizing the early period where the most rapid changes take place. The writer has tried to point out the advisability of this in a paper concerning the usefulness of curves.* It may be stated here that some of the conclusions in the present paper would have been lost entirely if not all stages of bacterial development had received equal attention.

The paper is divided into four chapters:

I. The extensive experiment covering the ammonia formation by *B. mycoides*, in five different soils, three different sands, in solutions and soil extracts, and the interpretation of the data.

II. A more detailed study of the mechanism of the ammonia production.

III. Experiments with other aerobic bacteria; and

IV. The requirements of anaerobic organisms.

I.—Bacillus Mycoides in Soils, Sands and Solutions.

Object.—The first and largest experiment shows the ammonia formation from peptone by *B. mycoides* in various media. Five different soils were used, namely, surface soil and subsoil from field 11 of the Experiment Station farm, two soils from adjacent fields, but of a widely different fertility, and fresh, brown peat from a swamp north of the college.

To compare these soils at the same moisture content would be unreasonable. To compare them at 1/3 or 2/3 of their water capacity, as Stevens did, is far better, yet arbitrary. The best results could be obtained only by testing each soil at various moisture contents and comparing the optimum conditions. This increases the extent of the experiment very much, but it was accepted as the least objectionable policy.

The amount that could be handled in one series was two soils at five different moisture contents and a quartz sand check, also at five different moisture contents, making a total of 30 distillations for each determination on account of the duplicates. All soils have also been tried with and without "fertilizer," i. e., potassium phosphate and calcium chloride.

Method.—The soils were air-dried, and the moisture content of the air-dry soils was determined by drying at 105°. The sands were heated with diluted hydrochloric acid, washed several times, first with tap water, then with distilled water, and then dried at 160° C.

The amount of soil corresponding to 50 g. of oven-dry soil was calculated and the corresponding weights were filled into liter flasks, 12 flasks for each moisture content of each soil to allow six duplicate determinations at different times. Since the experiment was to be carried on with strictly pure cultures, it seemed not advisable to keep all the soil of one kind in one container taking a sample of it whenever a determination was made, as this is generally done with non-sterilized soils. It would be almost impossible to avoid a contamination. It became, therefore, necessary to weigh out, sterilize and inoculate separately each lot used for a single determination. This complicated the experiment very much, since it required for duplicate determinations on six days for each

*Technical Bul. 5 (1910), Mich. Agr. College Exp. Station.

soil at five different moistures 5 x 12=60 flasks to be weighed out, sterilized and inoculated separately. This amount allowed duplicate determinations at five different times and one duplicate set of blanks. The peptone, 0.5 g. per 50 g. of oven-dry soil, was mixed with the soil before weighing out the individual sample, also the water in all cases where the soils were not too moist. The samples, each corresponding to 50 g. oven-dry soil, were placed into liter flasks, sterilized at 15 pounds pressure for 20 minutes, and stored in a room with a constant temperature of 18° until all the flasks for one set had been sterilized. They were then inoculated with ½ cc. of a 24 to 48 hours old culture of *B. mycoides* which had been transplanted in regular intervals in peptone solution. The culture was distributed in the soil by shaking as well as could be done; while it was not difficult to accomplish this with the sands and part of the soils, others contained enough loam to cake and the distribution seemed rather irregular. All the cultures were shaken again after one day's growth.

The ammonia in these cultures was determined after two, four, six, ten and twenty days by distilling it over with water and MgO into n/10 acid. Bacterial counts could not be made in this series, for lack of time, since the 30 distillations (three soils at five different moistures in duplicates) occupied practically a whole day. In some of the later experiments bacterial numbers and ammonia have been determined at the same time.

Data.—Table 1 gives all results of this first experiment. They are given in cc. n/10 ammonia per 50 g. of dry soil, after subtraction of the ammonia in the blanks. Instead of recording each of the duplicates as it was found, it seemed preferable to give the average of the two and the deviation. Thus, if the reading of the table is 7.2 cc. and the error +0.10, it means that the two determinations gave 7.1 and 7.3 cc. This way of recording allows a more ready comparison of the data and of the deviations by themselves.

This entire experiment with nearly 1,100 single determinations has been carried out by Mr. L. R. Himmelberger, to whom I am much indebted for this mass of data.

TABLE I.

Ammonia Formed by B. mycoides in 50 g. of Soil. (*Expressed in cc* $\frac{n}{10}$)

Series I.

	Moisture.	2 days		4 days.		6 days.		11 days.		21 days.		Average Error ±
		cc $\frac{n}{10}$ NH_3	Error ±	cc $\frac{n}{10}$ NH_3	Error ±	cc $\frac{n}{10}$ NH_3	Error ±	cc $\frac{n}{10}$ NH_3	Error ±	cc $\frac{n}{10}$ NH_3	Error ±	
Peptone solution	.....	0.5	0.75	1.8	0.05	3.0	0.30	5.8	0.20	6.1	0.15	0.30
Quartz Sand.	5%	1.2	0.05	1.7	0.55	3.8	0.25	3.2	0.45	1.3	0.05	0.27
	10%	2.7	0.25	4.6	0.35	4.8	0.40	5.1	0.15	4.9	0.15	0.26
	15%	2.3	0.35	4.7	0.40	6.1	0.20	5.5	0.30	6.2	0.45	0.34
	20%	3.4	0.20	4.8	0.10	6.0	0.15	6.3	0.15	7.1	1.15	0.35
	......	......	0.22	......	0.35	.....	0.25	.....	0.26	......	0.45	0.31
Surface soil........	5%	0	0.20	0	0.20	2.1	0.45	0	0.15	0.3	2.05	0.61
	10%	0.9	0.80	0.6	0.60	2.5	0.45	1.1	0.35	1.6	0.15	0.47
	15%	2.4	0.25	2.8	0.30	3.1	0.15	4.9	0.30	3.2	1.30	0.46
	20%	2.8	0.05	3.1	0.25	5.5	0.20	8.1	0.40	11.0	0.30	0.24
	25%	4.4	0.95	6.8	0.15	8.6	0.35	12.0	0.25	15.8	0.15	0.37
	......	......	0.45	......	0.30	......	0.32	......	0.29	......	0.79	0.43
Subsoil........................	5%	0	0.60	0	0.25	0	0.00	0	0.40	0	0.20	0.29
	10%	0	0.25	0	0.25	0.5	0.05	0	0.15	1.2	1.60	0.46
	15%	0	0.15	0.9	0.40	1.4	0.25	0.5	0.50	3.3	0.89	0.42
	20%	0.3	0.15	0.2	0.05	1.0	0.10	2.8	0.55	5.9	0.15	0.20
	25%	1.1	0	0.8	0.10	1.6	0.10	2.6	0.40	6.0	0.35	0.19
	......	......	0.23	......	0.21	......	0.10	......	0.40	......	0.62	0.31

Series II.

	Moisture.	2 days. $cc\ \frac{n}{10}\ NH_3$	2 days. Error ±	4 days. $cc\ \frac{n}{10}\ NH_3$	4 days. Error ±	6 days. $cc\ \frac{n}{10}\ NH_3$	6 days. Error ±	10 days. $cc\ \frac{n}{10}\ NH_3$	10 days. Error ±	20 days. $cc\ \frac{n}{10}\ NH_3$	20 days. Error ±	Average Error ±
Peptone solution	......	1.4	0.15	2.2	0.05	3.5	0.15	5.1	0.10	6.0	0.90	0.27
Quartz sand	10%	4.5	0.05	5.5	0.15	5.7	0.20	7.0	0.35	7.7	0.15	0.18
	15%	4.1	0.15	5.2	0.20	6.3	0.50	7.6	0.20	7.8	0.10	0.23
	20%	3.7	0.30	5.4	0.15	7.0	0.35	7.8	0.10	9.4	0.25	0.23
	25%	2.0	0.35	4.5	0	5.1	0.05	6.6	0.25	9.1	0.55	0.21
	......	......	0.21	......	0.13	......	0.28	......	0.23	......	0.25	0.22
Good soil A	10%	0.1	0.40	1.5	0.10	2.4	0.15	3.5	0.35	4.5	0.45	0.29
	15%	0.3	0.10	2.3	0.25	4.7	0.40	6.9	0.20	7.9	0.10	0.21
	20%	1.7	0.05	6.0	0.20	9.4	0.55	11.1	0.20	12.5	0.25	0.25
	25%	1.9	0.05	7.1	0.15	13.4	0.25	14.6	0.60	16.1	0.15	0.24
	30%	3.1	0.05	4.8	0.15	7.8	0.25	8.1	0.35	14.6	0.40	0.24
	......	......	0.13	......	0.17	......	0.32	......	0.34	......	0.27	0.25
Poor soil B	10%	0.6	0.10	0.3	0.20	2.2	0.30	2.3	0.10	2.8	0.15	0.17
	15%	1.5	0.15	0.2	0.10	7.0	0.40	9.6	2.10	7.7	0.10	0.57
	20%	0.4	0.20	4.0	1.25	7.6	0.20	12.1	0.45	12.3	0.25	0.47
	25%	0.8	0.65	3.3	0.25	8.0	0.30	11.9	2.00	14.4	0.20	0.68
	30%	0.9	0.80	2.8	0.60	7.5	0.10	10.8	0.20	13.7	0.15	0.37
	......	......	0.38	......	0.48	......	0.26	......	0.97	......	0.17	0.45

Series III.

	Moisture.	Minerals.	2 days. cc $\frac{n}{10}$ NH_3	2 days. Error ±	4 days. cc $\frac{n}{10}$ NH_3	4 days. Error ±	6 days. cc $\frac{n}{10}$ NH_3	6 days. Error ±	11 days. cc $\frac{n}{10}$ NH_3	11 days. Error ±	20 days. cc $\frac{n}{10}$ NH_3	20 days. Error ±	Average Error ±
Peptone solution	......	0	0.2	0.15	1.6	0.10	2.3	0.05	3.5	0.35	6.8	0.05	0.14
	......	+	1.0	0.25	2.6	0.35	3.3	0.20	7.2	0.45	10.9	0.30	0.31
Extract surface soil	......	0	0.7	0.05	1.2	0.10	3.0	0.15	5.8	0.10	10.0	0.20	0.12
	......	+	1.1	0.15	1.5	0.10	3.1	0.10	6.5	0.35	15.7	0.20	0.18
Extract subsoil	......	0	0.8	0.05	1.9	0.25	2.9	0.20	5.4	0.75	9.2	0.25	0.30
	......	+	1.4	0.25	2.1	0.15	2.9	0.10	5.9	1.05	15.0	0.15	0.34
	......	......	......	0.15	......	0.18	......	0.13	......	0.51	...	0.19	0.23
Quartz sand	20%	0	2.6	0.10	3.5	1.00	3.6	0.10	6.6	0.15	10.3	0.35	0.34
	20%	+	2.4	0.05	2.2	0.30	2.5	0.40	7.0	0.50	7.3	0.20	0.29
	......	......	......	0.07	......	0.65	......	0.25	...	0.33	......	0.28	0.32
Surface soil	15%	0	0	0.30	2.3	0.20	2.1	0.50	5.0	0.35	8.0	0.15	0.30
	15%	+	1.0	0.25	3.3	0.10	3.6	0.10	6.5	0.40	11.8	0.15	0.20
	25%	0	2.3	0.20	5.9	0.10	6.5	0.10	6.2	0.35	12.8	0.40	0.23
	25%	+	2.8	0.05	6.6	0.20	7.3	0.10	9.5	0.30	14.3	0.35	0.20
	......	......	......	0.20	......	0.15	......	0.20	......	0.35	......	0.26	0.23
Subsoil	15%	0	0.3	0.20	1.3	0.20	1.8	0.35	3.1	0.30	6.2	0.15	0.24
	15%	+	1.4	0.75	4.1	0.20	5.3	0.05	9.7	3.15	11.5	0.55	0.39
	25%	0	2.6	0.10	2.9	0.35	5.6	0.15	5.8	0.30	7.6	0.50	0.28
	25%	+	4.3	0.10	6.1	3.10*	8.3	0.15	10.0	6.05	14.7	0.40	0.22
	......	......	......	0.29	......	0.25	......	0.18	......	0.30	......	0.40	0.28

*Not included in averages.

Series IV.

	Moisture.	Minerals.	2 days.		4 days.		6 days.		10 days.		21 days.		Average Error ±
			cc $\frac{n}{10}$ NH_3	Error ±	cc $\frac{n}{10}$ NH_3	Error ±	cc $\frac{n}{10}$ NH_3	Error ±	cc $\frac{n}{10}$ NH_3	Error ±	cc $\frac{n}{10}$ NH_3	Error ±	
Peptone solution	.....	0	1.1	0.10	2.7	0.15	3.7	0.10	5.7	0.20	6.5	0.15	0.14
	.....	+	1.1	0.25	4.3	0.15	4.7	0.20	6.4	0.15	8.0	0.25	0.20
Extract soil A	.....	0	1.7	0.05	3.4	0.45	3.8	0.25	6.3	0.15	10.8	0.70	0.32
	.....	+	1.7	0.10	5.6	0.60	6.7	0.15	6.9	0.35	15.3	0.30	0.30
Extract soil B	.....	0	1.1	0.05	2.0	0.30	4.4	0.10	6.4	0.35	10.9	0.10	0.18
	.....	+	1.2	0.10	4.4	0.15	4.9	0.10	8.0	1.00	13.9	0.30	0.33
	.....	.....	.....	0.11	.....	0.30	.....	0.15	.....	0.37	.....	0.30	0.25
Quartz sand	20%	0	3.3	0.10	5.1	0.15	6.7	0.30	8.6	0.10	11.5	0.35	0.20
	20%	+	1.9	0.20	2.3	0.10	3.2	0.15	5.4	0.35	8.9	0.15	0.19
	.....	.....	.....	0.15	.....	0.13	.....	0.23	.....	0.22	.....	0.25	0.20
Good soil A	15%	0	0.9	0.40	3.2	0.05	5.1	0.05	6.5	0.40	11.6	0.10	0.20
	15%	+	1.7	0.20	3.6	0.05	5.8	0.20	9.2	.....	13.6	0.25	0.15
	25%	0	2.9	0.25	7.2	0.15	14.8	0.15	15.3	0.35	17.3	0.15	0.21
	25%	+	4.3	0.30	8.5	0.25	15.4	0.65	16.2	0.10	19.6	0.10	0.28
	.....	.....	.....	0.26	.....	0.13	.....	0.26	.....	0.28	.....	0.15	0.21
Poor soil B	15%	0	1.3	0.15	2.7	0.65	4.4	0.35	5.7	0.15	9.3	0.70	0.40
	15%	+	1.2	0.10	3.1	0.65	5.2	.....	6.7	0.30	13.4	0.45	0.38
	25%	0	1.6	0.10	3.8	0.60	9.0	0.15	11.3	0.20	14.0	0.10	0.23
	25%	+	2.7	0.25	5.8	0.10	13.8	0.40	15.1	0.15	17.9	.....	0.23
	.....	.....	.....	0.15	.....	0.50	.....	0.30	.....	0.20	.....	0.41	0.31

Series V.

	Moisture.	Minerals.	2 days. cc $\frac{n}{10}$ NH_3	2 days. Error ±	4 days. cc $\frac{n}{10}$ NH_3	4 days. Error ±	6 days. cc $\frac{n}{10}$ NH_3	6 days. Error ±	10 days. cc $\frac{n}{10}$ NH_3	10 days. Error ±	19 days. cc $\frac{n}{10}$ NH_3	19 days. Error ±	Average Error ±
Peptone solution	......	0	0.3	0.05	1.1	0.15	2.8	0.10	5.2	0.45	6.4	0.10	0.17
	......	+	0.5	0.05	1.2	0.15	3.4	0.05	6.0	0.10	7.7	0.05	0.08
Peat extract	......	0	1.6	0.05	2.9	0.10	4.9	0.25	7.0	0.20	12.9	0.05	0.13
	......	+	1.7	0.10	3.5	0.15	5.7	0.15	8.9	0.25	13.9	0.10	0.15
	......	......	......	0.06	......	0.14	.....	0.14	......	0.25	......	0.08	0.13
Quartz sand	10%	0	1.4	0.10	2.3	0.10	2.5	0.15	3.6	0.10	5.5	0.15	0.12
	15%	0	2.3	0.05	3.1	0.65	4.2	0.40	6.3	0.10	7.4	0.10	0.26
	15%	+	2.1	0.15	2.9	0.05	4.8	0.10	6.8	0.05	7.6	0.15	0.10
	25%	0	1.4	0.65	3.2	0.65	5.0	0.25	5.9	0.20	8.5	0.20	0.39
	25%	+	1.9	0.20	3.4	0.65	7.1	0.35	8.6	......	9.8	0.05	0.25
	......	......	......	0.23	......	0.42	......	0.25	......	0.09	......	0.13	0.22
Peat	45%	0	0	0.40	0.5	0.20	0.7	0.10	2.2	0.20	2.3	0.05	0.19
	60%	0	3.9	0.15	4.4	0.45	5.0	0.10	7.0	0.75	10.4	0.55	0.40
	60%	+	4.4	0.15	4.5	0.50	5.5	0.10	8.8	0.20	11.5	0.55	0.30
	75%	0	5.0	0.25	5.5	0.05	7.5	0.15	8.6	0.15	13.5	0.15	0.15
	75%	+	6.2	0.35	6.4	0.35	8.2	0.05	10.0	0.25	15.1	0.15	0.23
	......	......	......	0.26	......	0.31	......	0.10	......	0.31	......	0.29	0.25

Series VI.

	Moisture.	2 days. cc $\frac{n}{10}$ NH_3	2 days. Error ±	4 days. cc $\frac{n}{10}$ NH_3	4 days. Error ±	6 days. cc $\frac{n}{10}$ NH_3	6 days. Error ±	11 days. cc $\frac{n}{10}$ NH_3	11 days. Error ±	21 days. cc $\frac{n}{10}$ NH_3	21 days. Error ±	Average Error ±
Peptone solution	......	1.4	0.35	2.6	0.05	3.7	(4.5)	4.3	0.40	6.9	0.15	0.24
Coarse sand	10%	3.5	0.10	4.2	0.10	6.5	0.35	7.0	0.10	8.2	0.15	0.16
	15%	4.2	0.10	4.9	0.05	7.8	0.35	8.5	0.25	9.1	0.10	0.17
	20%	3.6	0.05	4.0	0.20	6.3	0.30	7.7	0.05	8.0	0.05	0.13
	......	......	0.08	......	0.12	......	0.33	......	0.13	......	0.10	0.15
Medium sand	10%	1.4	0.15	3.8	0.20	5.5	0.20	7.1	0.10	7.8	0.25	0.18
	15%	3.1	0.10	5.3	0.15	6.4	0.15	8.2	0.05	8.9	0.25	0.14
	20%	3.0	0.10	4.9	0.15	6.5	0.10	8.5	0.30	8.9	0.15	0.16
	25%	2.4	0.15	4.2	0.65	5.4	0.40	9.1	0.10	9.5	0.15	0.29
	......	......	0.13	......	0.29	......	0.21	......	0.14	......	0.20	0.19
Fine sand	15%	0.8	0.15	1.2	0.10	3.6	0.15	3.8	0.05	4.3	0.15	0.12
	20%	1.1	0.10	1.6	0.15	4.0	0.15	4.1	0.10	4.8	0.05	0.11
	25%	2.9	0.20	5.1	0.15	6.4	0.05	6.8	0.10	7.8	0.10	0.12
	30%	1.4	0.10	2.9	0.25	4.4	0.15	4.8	0.10	5.9	0.05	0.13
	......	......	0.14	......	0.16	......	0.13	......	0.09	......	0.09	0.12

Average Errors.—Since these data will be used for a very extensive discussion, it is necessary to realize how large the probable error is in order to avoid conclusions which have no other basis than an analytical error. Of the 540 duplicate determinations, only seven showed such a difference that they were excluded from the averages, or rather that only the probable datum was taken while the other one was discarded. There are three in series iii.; three in series iv.; and one in series vi. They are considered by the author as due to contaminations or incomplete sterilization, though no proof can be given, since the deviation could not be discovered until the distillation was finished. The grand average error of all other 533 duplicates is ±0.25 cc. of n/10 NH_3. The averages are simple arithmetical averages; the method of the least squares was not used because of the amount of work involved.

The error is largely due to the analytical method, and only to a slight degree dependent upon variation in the microbial growth, since it increases but very little with the increasing amounts of ammonia.

Average Error of All Determinations.

	2 days.	4 days.	6 days.	10 days.	20 days.
All soils and sands	0.22	0.26	0.23	0.29	0.31
All solutions	0.18	0.17	0.16	0.34	0.24

The increase from 0.22 to 0.31 and from 0.18 to 0.24 (0.34) is very slight in comparison with the increase of ammonia, which is about four to five times as large after 20 days as it is at two days. The error due to a variation in culture is only (0.31—0.22)=0.09 cc. in soils and sands, and 0.06 to 0.16 cc. in solutions, which compares very favorably with the analytical error, 0.22 and 0.18 cc. respectively. The development of duplicate pure cultures seems to be quite regular in soils as well as in solutions. It must be remembered, however, that the culture had been grown for many generations in the standard peptone solution, and was more homogenous, perhaps, than the ones employed in most laboratory experiments.

A comparison of the average error of the different series shows a continuous decrease.

Series	I.	II.	III.	IV.	V.	VI.
Average Error	0.35	0.31	0.27	0.24	0.20	0.18

Whether this is due to an improvement in the technic or to a more complete acclimatization of the culture cannot be stated. There was a difference of about three months between the inoculation of the first and last series, and during all this time and about two weeks previous to the first inoculation the culture had been grown in peptone solution.

The average error is also a good test for the even distribution of bacteria in soils. The average error of the different soil types compares as follows:

AVERAGE ERROR OF DIFFERENT SOIL TYPES.

All quartz sands	±0.24 cc.	All soils A	±0.23 cc.
All surface soils	±0.33 cc.	All soils B	±0.38 cc.
All subsoils	±0.20 cc.	All peats	±0.25 cc.
All solutions	±0.22 cc.		

Evidently Soil B gave the greatest difficulties in mixing and in distributing the bacteria, while Soil A and the sands allowed an almost perfect mixture, being nearly equal to that in solutions which must be considered perfect.

The conclusions from the errors are made a little doubtful, however, by the results of the last series, where the average error of the fine sand cultures is smaller than that of the coarse and medium sand cultures. This is greatly improbable since it took much shaking to distribute the inoculum in the fine sand, while in the coarse and medium sand no difficulties were found.

Variation Between the Different Series.—While the duplicate determinations of the same series check quite closely, there is a considerable deviation in the development of the same culture in the different series. This comes partly from the variations of the ammonia in the blank determinations which is subtracted from the ammonia found in the cultures. But that alone does not account for the difference, and it must be assumed that other factors, as yet unknown or at least beyond control, leave their trace in the variation of the cultures. The cultures in peptone solution and in medium sand carried on in each series give the data for comparison. (Table 11.)

TABLE II.

Ammonia Formed in 50 g. of Sand. (Compiled from Table I.)

Series.	Moisture.	2 days.	4 days.	6 days.	10 days.	20 days.
I	5 %	1.2	1.7	3.8	3.2	1.3
I	10 %	2.7	4.6	4.8	5.1	4.9
II	10 %	4.5	5.5	5.7	7.0	7.7
V	10 %	1.3	2.2	2.4	3.5	5.4
VI	10 %	1.4	3.8	5.5	7.1	7.8
Average	10 %	2.6	4.0	4.6	5.7	6.5
I	15 %	2.3	4.7	6.1	5.5	6.2
II	15 %	4.1	5.2	6.3	7.6	7.8
V	15 %	2.5	3.3	4.4	6.5	7.6
VI	15 %	3.2	5.4	6.5	8.2	9.0
Average	15 %	3.0	4.7	5.4	7.0	7.7
I	20 %	3.4	4.8	6.0	6.3	7.1
II	20 %	3.7	5.4	7.0	7.8	9.4
III	20 %	2.6	3.5	3.6	6.6	10.0
IV	20 %	3.4	5.2	6.8	8.7	11.6
VI	20 %	2.9	4.8	6.4	8.4	8.8
Average	20 %	3.3	4.7	6.0	7.6	9.4
II	25 %	2.0	4.5	5.1	6.6	9.1
V	25 %	1.5	3.3	5.1	6.0	8.6
VI	25 %	2.4	4.2	5.4	9.1	9.5
Average	25 %	2.0	4.0	5.2	7.2	9.1
I	Peptone Solution	0.5	1.8	3.0	5.8	6.1
II		1.4	2.2	3.5	5.1	6.0
III		0.2	1.6	2.3	3.5	6.8
IV		1.1	2.7	3.7	5.7	6.5
V		0.3	1.1	2.8	5.2	6.1
VI		1.4	2.6	3.7	4.3	6.9
Average	"	0.8	2.0	3.2	4.9	6.5

In the peptone solutions there is no series which is in every distillation the lowest or the highest. However, in Series III, three of the five data are lower than the corresponding figures of the other five series, while in Series IV, two data are the maximum numbers (see Table II). The greatest deviations between these series are, at the five different times 1.2 cc., 1.6 cc., 1.4 cc., 2.3 cc., and 0.9 cc. respectively. This indicates that the difference does not increase with the age of the culture, and since it does not increase absolutely, it decreases relatively because the total amount of ammonia increases. The greatest variation between peptone solutions of the different series, expressed in per cents of the

average total ammonia formed, amounts to ± 75% after two days, 40% after four days, 22% after six days, 24% after 10 days and 7% after 20 days. This means, in non-mathematical terms, that the older the cultures the better comparable are the data.

Among the sand cultures there is one series lower than all others, namely Series V. An explanation for it cannot be given. None of the series shows permanently higher data than the others. The greatest deviation of corresponding cultures of different series is shown in the following table.

TABLE III.

Maximum Deviation of Quartz Sand Cultures of Different Series.

Moisture.	2 days.	4 days.	6 days.	10 days.	20 days.	Average.
10%	3.2	3.3	3.3	3.5	2.8	3.2
15%	1.8	2.1	2.1	2.7	2.8	2.3
20%	1.1	1.9	3.4	2.4	4.5	2.7
25%	0.9	1.2	0.3	3.1	0.9	1.3
Average	1.8	2.1	2.3	2.9	2.8	2.4

The maximum deviation between corresponding cultures seems to increase slightly with age, but not nearly as fast as the total ammonia, so that the relative error becomes smaller with the age of culture.

Comparison of Solutions, Soil and Sand Cultures.—The true picture of the average development of *B. mycoides* in sand cultures and in solution is represented in the averages shown in Table IV. The optimum moisture for *B. mycoides* in this quartz sand is about 20%. The series with 5% moisture is better omitted from consideration, being based on only one set of duplicates with rather questionable data. The series with 10% moisture has the same endpoint as the peptone solution, but ferments much faster in the beginning. The cultures with 15% are superior in every point, and the cultures with 20% are higher again than those with 15%. A further increase of moisture lowers the amount of ammonia formed. The peptone solution might be considered as the extreme of the increase of moisture, the sand disappearing completely.

TABLE IV.

Ammonia formed in Quartz Sand and in Peptone Solution. (Averages from Table II.)

	2 days.	4 days.	6 days.	10 days.	20 days.
5% moisture (1 duplicate)	1.2	1.7	3.8	3.2	1.3
10% moisture (4 duplicates)	2.6	4.0	1.6	5.7	6.5
15% moisture (4 duplicates)	3.0	4.7	5.1	7.0	7.7
20% moisture (5 duplicates)	3.3	4.7	6.0	7.6	9.4
25% moisture (3 duplicates)	2.0	4.0	5.2	7.2	9.1
Peptone solution (6 duplicates)	0.9	2.0	3.2	5.0	6.5

The four soils of the first two series show the moisture optimum at 25%. They differ from the sand in their very weak development at 10%, while they are superior to sand at 20 to 30%. The surface soil of Series I is a much better medium for *B. mycoides* than the subsoil, showing nearly twice as high an endpoint. In the earlier stages of the bacterial growth this difference is much larger and it seems as if the

bacteria in the subsoil are retarded by some inhibiting factor that they finally overcome. The same soils in Series III behave quite differently. The surface soil yields a little less ammonia, the subsoil considerably more than in the first series. The soils of both series are from the same sample which had been kept air-dry during the five weeks which lay between the first and third series. The drying and exposure to air had improved the subsoil to such a degree that after the addition of fertilizer it gave slightly larger ammonia yields than the fertilized surface soil. Even if the two different soils were not a mutual check in themselves, the comparison of the sand cultures and of the peptone solution shows that the differences between Series I and III cannot be laid to the inoculum.

The soils A and B of Series II and IV do not show as much difference as the surface and subsoils; in fact, the difference is practically negligible. In Series IV, after the soils had been kept dry for about five weeks, Soil B showed no change, while Soil A had slightly improved.

In comparing the action of *B. mycoides* upon peptone in sand and in soils, it would not be permissible to compare the cultures of one certain arbitrary moisture content. It seems fair, however, to compare them at their optimum of ammonia production. This is 25% for the first four soils, 20% for sand and 75% for peat. The maximum values for each soil after 20 days are:

With surface soil	15.8	cc. $\frac{n}{10}$	NaOH	With peat	13.5	cc. $\frac{n}{10}$	NH_3
" subsoil	7.6	"	"	" sand	11.6	"	"
" soil *A*	17.3	"	"	" solution	6.9	"	"
" soil *B*	14.4	"	"				

According to these data, Soil A is the best culture medium for *B. mycoides*, and the subsoil is the poorest. It seems remarkable that the amount of ammonia in the best soil is only twice as large as that in the poorest soil. Solution and subsoil are almost alike in their ammonia formation.

Fertilizer Effects.—The object of Series III, IV and V was to ascertain whether and to what extent the better growth in certain soils could be accounted for by the presence of soluble mineral salts. The "fertilizer" used consisted of 0.2 g. of KH_2PO_4 and 0.1 g. $CaCl_2$ per 50 g. of dry soil or 50 cc. of solution respectively. In Series V the monabasic phosphate was substituted by the dibasic phosphate.

The influence of the fertilizer is favorable in every instance except with quartz sands. This is an apparently peculiar fact which, however, can be explained. In Series III the fertilized sand culture showed in the average 2.0 cc. less ammonia than the unfertilized check, while the treated peptone solution was 2.1 cc. higher than the unfertilized solution. In Series IV, the minerals decrease the ammonia production in sand 2.7 cc., while the same minerals cause an increase of 0.9 cc. in the corresponding solution. In Series V, the effect of the minerals is not the same upon sand, causing a rise of 0.2 cc. at 15% moisture and of 1.5 cc. at 25%. It is true that in Series V, the monobasic phosphate was substituted by the dibasic which causes a change of acidity. But the acidity was also in the peptone solution, and yet, there was an increase in the peptone solution due to the same salt that caused a decrease in the sand culture. The difference between the sand and the solution lies in the amount of moisture in which the salts are

dissolved. The 0.2 g. of KH_2PO_4 dissolved in 50 cc. of liquid make a solution of 0.4%. The same amount in 50 g. of sand with 20% moisture, i. e. with 10 g. of H_2O makes a 2% solution. The acidity of this latter solution, 5 times as high as in the former, may possibly retard the growth while a 0.4% solution is useful by furnishing valuable food. With this supposition agrees the circumstance that in Series V, the average increase due to the minerals is only 0.2 cc. at 15% moisture, while at 25% moisture the minerals being more diluted, the increase is 1.5 cc. In the soils, the acidity is probably neutralized by the lime of the soil, and the minerals prove helpful in every case, though the degree varies with the soils. Table V gives the average increase of the fertilized cultures over the corresponding unfertilized samples.

TABLE V.

Increase of Ammonia Due to Mineral Salts.

Culture.	Moisture.	Series.	2 days.	4 days.	6 days.	10 days.	20 days.	Average.
Surface soil	15 and 25%	III	0.75	0.85	1.15	2.40	2.65	1.60
Subsoil	15 and 25%	III	1.40	3.50	3.10	5.40	6.20	3.90
Soil A	15 and 25%	IV	1.10	0.85	0.65	1.80	2.15	1.30
Soil B	15 and 25%	IV	0.50	1.20	2.80	2.40	4.00	2.15
Peat	60 and 75%	V	0.85	0.50	0.60	1.60	1.35	1.00
Average of all soils			0.94	1.38	1.66	2.72	3.27	2.00
Average of all sands			−0.3	−1.0	−0.5	+0.1	−1.0	−0.5
Average of all peptone solutions			0.2	0.9	0.9	1.7	2.3	1.2
Average of all soil extracts			0.2	1.2	0.9	1.1	4.0	1.5

The two unproductive soils, the subsoil and Soil B, react very promptly upon the fertilizer, while the surface soil, Soil A and the peat show a much smaller increase, about 1.6 cc. in the average against 3.0 cc. in the unproductive soils. In the soils as well as in the liquid cultures, the effect of fertilizers increases with the age of the culture to such an extent that the increase is at least proportionate with the increase of total ammonia.

The Same Data on the Basis of Soil Solution.—In all previous discussions, the ammonia has been computed on the basis of 50 g. dry soil or 50 cc. of solution respectively. This method is quite customary in soil bacteriology and it has been used in the first pages of this paper purposely to show that it is absolutely impossible for bacteriological experiments. It may be proper to say that Soil A produces 15 cc n/10 NH_3, and it produces more at 25% moisture than at 20%. But if one were to conclude from that, that the bacteria thrive better at 25% than at 20% moisture, one would make a serious error. If one compares bacterial activity, there is only one basis permissable, namely equal amounts of medium. The medium is the soil solution only, not the undissolved soil particles, and a comparison must be based upon equal volumes of soil solution. To compare 100 g. of soil with 10% moisture and 100 g. of the soil with 20% moisture would be just as unreasonable as to compare the amount of acid formed in 10 cc. of one milk and in 20 cc. of another. How much reason the soil chemist might have for figuring his analysis per 100 g. of dry soil, the soil bacteriologist can not possibly follow this procedure if he wants to know anything about bacterial development in the soil.

One may object, that the soil as such has a great influence upon the growth of microörganisms. That is beyond doubt. But it must be admitted that in order to determine the influence of phenol upon bacteria, we do not figure our data per gram of phenol, but per 100 cc. of nutrient solution. On the contrary, the introduction of the soil into the basis of comparison makes the data obscure. This is easily demonstrated in the case where the soil does not affect the bacterial development. If a stone weighing 100 g. is added to 100 cc. of a pure culture of *B. mycoides*, and 2 stones of 100 g. each to another 100 cc. of a pure culture of *B. mycoides*, it is evident that the development is practically the same in both cases, but the computation per "100 g. of dry soil" shows the first culture to give twice as high data as the second. An example of the perplexities encountered in figuring on the soil as a basis has been given already in the influence of acid phosphate upon the sand cultures.

Stevens and Withers* have considered the possibilities of using the soil solution as the basis of all comparison, and have computed their data accordingly. But they did not continue in their policy. "This method of comparison probably tends to exaggerate the value of the changes occurring, and from a practical viewpoint a comparison by the third method is probably the most serviceable since it pictures approximately the relative nitrifying power of two cultures of equal weight." It is the author's belief that the "practical viewpoint" of Stevens and Withers prevented them from obtaining the data and conclusions presented in this paper.

For this reason, all further discussion of experiments is based on equal amounts of liquid medium. All data of Table I have been computed in mg. NH_3 per 100 cc. of soil solution. Table VI shows data which will lead to conclusions essentially different from, and even contrary to those of the former paragraphs.

TABLE VI.

Milligrams NH_3 formed by Bacillus mycoides in 100 cc. Soil Solution.

Series I.

	Moisture of soil.	2 days.	4 days.	6 days.	11 days.	21 days.
Surface	10 %	27.6	18.4	76.5	33.7	49.0
	15 %	46.2	53.9	59.7	94.2	61.8
	20 %	38.1	42.2	74.5	110.0	150.0
	25 %	44.7	69.1	87.3	122.0	max.160.4
Subsoil	15 %	0	17.3	26.9	9.6	63.5
	20 %	4.1	2.7	13.6	38.1	80.2
	25 %	11.2	8.1	16.2	26.4	61.0
Quartz sand	5 %	77.6	110.0	245.0	206.0	84.0
	10 %	82.5	140.6	146.9	156.0	150.0
	15 %	44.4	90.4	117.5	106.0	119.3
	20 %	46.3	65.2	81.6	85.7	96.6
	25 %	....	....	....	....	....
Solution	....	1.7	6.1	10.2	19.7	20.8

*Centralblatt f. Bakt. II Abteilung, Bd. 23, p. 372.

Series II.

Soil.	Moisture.	2 days.	4 days.	6 days.	10 days.	20 days.
Good soil A	10%	3.1	46.0	73.5	107.0	138.0
	15%	5.8	41.4	90.5	133.0	152.0
	20%	23.2	81.7	128.0	151.0	170.0
	25%	19.3	72.2	136.5	149.0	164.0
	30%	24.6	38.0	61.8	61.2	115.5
Poor soil B	10%	18.4	9.2	67.3	70.3	85.7
	15%	29.0	3.9	135.0	185.0	148.0
	20%	5.5	54.4	103.5	165.0	167.0
	25%	8.2	33.6	81.5	121.0	117.0
	30%	7.1	22.2	59.5	85.5	109.0
Quartz sand	10%	138.0	168.0	174.0	211.0	236.0
	15%	79.0	100.0	121.0	147.0	150.0
	20%	50.4	73.5	95.3	106.0	128.0
	25%	20.4	45.8	52.0	67.2	92.8
Peptone solution	(100%)	4.8	7.5	11.9	17.4	20.4

Series III.

Soil.	Moisture.	2 days.	4 days.	6 days.	11 days.	20 days.
Surface soil:						
Untreated	15%	0.	44.4	40.5	96.5	151.5
Untreated	25%	23.4	60.0	67.2	63.2	130.5
Treated	15%	19.3	63.7	69.4	125.0	227.0
Treated	25%	28.5	67.2	74.4	96.7	146.0
Subsoil:						
Untreated	15%	5.8	25.1	31.7	59.8	120.0
Untreated	25%	26.5	29.5	57.0	59.1	77.5
Treated	15%	26.0	79.0	102.0	187.0	223.0
Treated	25%	43.8	62.2	84.5	102.0	150.0
Quartz sand:						
Untreated	20%	35.4	47.7	49.0	90.0	140.0
Treated	20%	32.7	30.3	34.1	95.4	99.3
Peptone solution:						
Untreated		0.7	5.4	7.8	11.9	23.2
Treated		3.4	8.8	11.2	24.5	37.0
Surface soil extract:						
Untreated		2.4	4.1	10.2	19.7	34.0
Treated		3.7	5.1	10.5	22.1	53.4
Subsoil extract:						
Untreated		2.7	6.5	9.9	18.4	31.3
Treated		4.8	7.2	9.9	20.1	51.0

Series IV.

Soil.	Moisture.	2 days.	4 days.	6 days.	10 days.	21 days.
Good soil A:						
Untreated	15 %	17.3	61.8	98.3	125.0	224.0
Untreated	25 %	29.5	73.3	151.0	156.0	176.0
Treated	15 %	32.7	69.5	112.0	177.0	263.0
Treated	25 %	43.8	86.5	157.0	165.0	200.0
Poor soil B:						
Untreated	15 %	25.0	52.0	81.7	110.0	179.0
Untreated	25 %	16.3	38.6	91.6	115.0	142.5
Treated	15 %	23.1	59.8	101.0	129.0	258.0
Treated	25 %	27.5	59.0	141.0	154.0	182.0
Quartz sand:						
Untreated	20 %	45.0	69.4	91.2	117.0	157.0
Treated	20 %	25.9	31.3	43.6	73.5	121.0
Peptone solution:						
Untreated	....	3.7	9.2	12.6	19.4	22.2
Treated	....	3.7	14.6	16.0	21.8	27.2
Extract soil A:						
Untreated	....	5.8	11.6	12.9	21.4	36.7
Untreated	....	5.8	19.1	22.8	23.5	52.0
Extract soil B:						
Untreated	....	3.7	6.8	15.0	21.8	37.0
Treated	....	4.1	15.0	16.7	27.2	47.3

Series V.

Soil.	Moisture.	2 days.	4 days.	6 days.	10 days.	19 days.
Peat:						
Untreated	45 %	0.	2.1	2.9	9.1	9.6
Untreated	60 %	8.8	10.0	11.4	15.9	23.6
Untreated	75 %	5.7	6.2	8.5	9.8	15.9
Treated	60 %	10.0	10.2	12.5	20.0	26.1
Treated	75 %	7.0	7.3	9.3	11.4	17.1
Quartz sand:						
Untreated	10 %	42.8	70.3	76.4	110.0	168.0
Untreated	15 %	44.3	59.8	81.0	121.5	142.5
Untreated	25 %	14.3	32.6	51.0	60.1	86.5
Treated	15 %	40.5	56.0	92.5	131.0	146.5
Treated	25 %	19.3	34.6	72.2	87.5	100.0
Peptone solution:						
Untreated	....	1.0	3.7	9.5	17.7	21.0
Treated	....	1.7	4.1	11.6	20.4	26.2
Peat extract:						
Untreated	....	5.4	9.9	16.7	23.8	43.8
Treated	....	5.8	11.9	19.4	30.3	47.3

Series VI.

Soil.	Moisture.	2 days.	4 days.	6 days.	11 days.	21 days.
Coarse sand	10%	107.0	128.5	199.0	214.0	251.0
	15%	81.0	94.5	150.5	164.0	176.0
	20%	49.0	54.3	85.5	104.5	109.0
Medium sand	10%	42.7	116.0	168.0	217.0	238.0
	15%	59.7	102.0	123.5	158.0	172.0
	20%	40.7	66.6	88.3	115.7	121.0
	25%	24.4	42.8	55.0	92.8	97.0
Fine sand	15%	15.4	23.2	69.5	73.3	83.0
	20%	15.0	21.8	54.3	55.8	65.2
	25%	29.5	52.0	65.2	69.2	79.4
	30%	11.1	23.0	34.8	38.0	46.7
Peptone solution		4.8	8.8	12.6	14.6	25.5

New Comparison of Sand, Soil and Solution.—These data are not absolutely comparable (nor were the previous ones.) on account of the peptone being added in proportion to the weight of sand or soil. Consequently, the sand with 5% moisture and 1% peptone actually contains a solution of 20% peptone which is compared with a 1% peptone solution in the liquid culture. As far as the peptone itself is concerned, this does not make a serious difference, because a bacterium that decomposes only one-fifth of its food in a 1% solution of peptone will not be able to destroy more in a 20% solution.* But considering the fact that in the sand cultures, the mineral matter is very scarce, coming entirely from the commercial peptone, it is evident that a more concentrated peptone solution is better suited for growth on account of providing more material for cell construction. However, three of these series have been checked with parallel cultures which contained mineral fertilizers, and in those, the increase of ammonia due to minerals averaged not more than 40% while the differences we are dealing with in this experiment amount to several hundred per cent. Later experiments will show that the differences are similar even when the peptone concentration is constant. They demonstrate further that the supposition of some easily decomposed nitrogenous compounds in the peptone cannot be accepted as an explanation.

TABLE VII.

Influence of Quartz Sand upon the Ammonification by B. mycoides. Averages of Sand Cultures from Table VI.

Moisture content of sand.	Series of experiments.	Peptone concentration.	2 days.	4 days.	6 days.	10 days.	20 days.
5%	I	20%	72.5	110.0	215.0	206.0	84.0
10%	I, II, V, VI	10%	79.5	122.2	140.5	171.5	205.0
15%	I, II, V, VI	6.7%	57.8	90.5	101.0	134.8	148.3
20%	I, II, III, IV, VI	5%	44.8	63.8	81.6	103.3	127.9
25%	II, V, VI	1%	20.4	40.7	53.0	73.3	92.8
(100%) solution	I, II, III, IV, V, VI	1%	2.7	6.8	10.9	16.7	22.2

*Later experiments, soon to be published have shown that concentration of peptone plays a more important part than was assumed in drawing these conclusions.

The data concerning ammonia production in quartz sand are summarized in Table VII. This table corresponds to Table III and illustrates as plainly as can be desired, the reason why the soil solution has been chosen for a basis. From Table III, it was concluded that the optimum moisture for ammonia formation in quartz sand is 20%, that the decomposition at 5% was negligible and that the peptone solution equaled, in its suitability for *B. mycoides*, the sand with 10% moisture. These conclusions must be revised, because they have been drawn without regard to the most vital needs of microörganisms, namely the moisture. While Table III says that the "soil" produces most ammonia at 20% moisture, Table VII shows that the "bacteria" grow best at 10% moisture. While Table III indicates that the soil with 10% moisture produces about as much ammonia as the solution, Table VII demonstrates that the bacteria in the soil with 10% moisture develop about 8 to 9 times as fast as they do in solution.

These two sets of data are not contradictory. Table III represents the standpoint of the farmer who wants the product regardless of where it comes from. Table VII represents the view point of the scientist who wants to study the conditions of existence in the soil. The results become contradictory only if conclusions are drawn without due regard to the points emphasized. The fact that 100 g. of sand + 20 cc. of water produce more ammonia than 100 g. of sand + 10 cc. of water, does not allow the conclusion that the bacteria grow better in sand + 20% moisture. Table VII shows that the opposite is the case. But this last statement does not interest the farmer; he wants the largest amount possible in his soil, not in his soil solution. The only possible way of studying life conditions in soil is, of course, that of Table VII.

The sand cultures show an increase of 318 to 823% over the solutions which is due entirely to the physical qualities of the sand, all chemical factors being excluded. The soils show less ammonia formation than the sand cultures. If we compile the largest amount of ammonia formed in each soil the following data are obtained:

Surface soil,	160 mg.	Peat	24 mg.
Subsoil,	120 "	Sand	238 "
Soil A,	224 "	Solution	23 "
Soil B,	179 "		

These data should be compared with those on page 21. Here again, the contrast of the two viewpoints is very striking. The best medium for *B. mycoides* is evidently the sand, where it produced 10 times as much ammonia as in the solution. The peat is such an inadequate medium for *B. mycoides*, so much inferior even to the subsoil that one is led to believe in some antiseptic property of peat. The physical soil properties of peat, especially as far as ventilation is concerned, are

doubtless very unfavorable for aerobic bacteria. It must be further considered that a large portion of the moisture in peat is not available for bacterial development, and that the decomposition probably took place in a water volume much smaller than the one used in the computation. This might easily double the amount of ammonia produced per 100 cc.

Influence of the Moisture Film.—The enormous increase of microbial development in sand can be explained only by the enormously increased ventilation of the culture. The chemical mechanism of the relation between ventilation and development is treated in detail in the following chapter, because more experiments are necessary for this investigation. The data of the preceding experiments are fully sufficient however, to discuss the influence of moisture upon the development of bacteria.

Table VII has shown *B. mycoides* to develop best in sand with 10% moisture. If it grows better at 10% than at 15% moisture, this is evidently due to better aeration. One should suppose therefore that this would be the case in all soils. However, according to Table VI, the best conditions are found at 20% in all the four soils, and at 10% moisture content, the development is not as good though the aeration is doubtless better. This seemed strange and contradictory at first; the too concentrated soil solution in the drier soils cannot serve as an explanation because in these same soils, the addition of mineral salts, i. e. an increase in the concentration, caused a higher yield of ammonia. The supposition of harmful soil compounds exerting their influence more strongly in the drier soils is perhaps possible, but without any proof.

A satisfactory solution of this problem was finally found by the following reasoning: Decreasing moisture content increases the aeration, and increasing aeration causes increased development of aerobic bacteria. This relation is not unlimited, however, because in the perfectly dry soil which has the greatest aeration, the bacterial growth is not optimal, but zero. Consequently, soil can get too dry for bacterial development. We are dealing with a film of moisture surrounding the soil particles. If this film becomes so thin that food can no longer diffuse to the cells, the life manifestations of bacteria must cease. The thickness of the moisture film grows in direct ratio with the grainsize, and since the four soils under study have a considerably smaller grainsize than the medium sand, it follows that their films are considerably thinner than that of the sand cultures, or that more water is necessary to bring them up to the optimum film thickness.

The moisture film as essential factor in the microbiology of soils has already been mentioned nearly 30 years ago by Soyka*. His main experiment is mentioned on page 36.

*Pettenkofer und Ziemssen, Handbuch der Hygiene, Teil I, Abteilung II, Der Boden, p. 228. 1885

The Relation between Grain Size and Surface Film can be computed fundamentally in the following way under the supposition that the grains are spherical: The diameter of the grain be a mm. The volume of one grain is $\frac{4}{3}\left(\frac{a}{2}\right)^3\pi = \frac{a^3}{6}\pi$ The average specific gravity of soil particles is not very far from 2.6. The weight of one particle is therefore $\frac{2.6\ a^3\ \pi}{6}$ mg. and one milligram contains $\frac{6}{2.6\ a^3\ \pi}$ particles. The surface of one such particle is $4\left(\frac{a}{2}\right)^2\pi = a^2\pi$. square millimeters and the surface of all particles in 1 mg. of soil is $\frac{6\ a^2\ \pi}{2.6\ a^3\ \pi} = \frac{6}{2.6\ a}$ square millimeters. In 100 g. of soil, the surface of all particles is $\frac{600{,}000}{2.6\ a} = \frac{230{,}000}{a}$ square millimeters.

$= \frac{2300}{a}$ square centimeters.

If b cc. of liquid are added to 100 g. of this soil, it will be spread out over a surface of $\frac{2300}{a}$ square centimeters, and the liquid film will be $f = \frac{b.\ a.}{2300}$ cm. thick. It is more convenient to compute the surface film in microns. The thickness of the moisture film with a grain size of a mm. diameter and with b parts of moisture in 100 g. of dry soil (not per cents of moisture) is $f = 4.3\ a\ b$ microns.

This formula is accurate only with round particles. If they are cube-shaped, the surface is 38% larger, and the film will be consequently 38% thinner. The more irregular the surface, the thinner will be the film diameter at the same grain diameter. It is hardly imaginable, however, that the shape of the soil particles will be so odd-shaped as to have a surface more than twice as large as that of spheres. The factor 4.3 may therefore become as small as 2.0 in some cases, but probably not smaller.

It may be unnecessary to call attention to the fact that a moisture film as it is computed here, does not really exist. The water in the soil forms by no means an even film over the entire inner surface of the soil, but gathers at the places where the soil particles touch. The "thickness of the moisture film" is solely an expression for a certain condition in the soil, it allows us to figure with an essential factor in bacterial life that cannot be expressed precisely by one single term. Though the moisture film is mentioned continuously in the future discussions, it should always be interpreted under the just mentioned limitations.

Table VII showed the optimal moisture content for *B. mycoides* in medium sand to be between 5 and 10%. The data obtained with 5% moisture are unreliable and do not check with each other. Generally the sand with 10% moisture seems to afford a better medium, and the real optimum lies between the two. According to the above-mentioned formula, the moisture film would be 22 — 43 μ figuring on 1 mm. grainsize and round grains. Since the grains are quite angular and irregular (see Figure 1) the film is probably only half as thick, approximately 10 — 20 μ. This film would suffice to surround bacteria and even smaller protozoa entirely with water. If this film decreases in thick-

ness, the diffusion becomes smaller. Though this does not change the coefficient of diffusion, i. e. the amount of compounds diffusing per unit, it decreases the number of units and consequently the amount of food diffusing towards the cells and the amount of metabolic products diffusing from the cells. The result is an insufficient food supply combined with the accumulation of harmful products. The most abundant oxygen supply could not increase the rate of development under these conditions. The greatest development will take place when oxygen and food diffuse to the cell at least as fast as they are used up; the demand for both increases with the growth of the cells because the active mass increases.

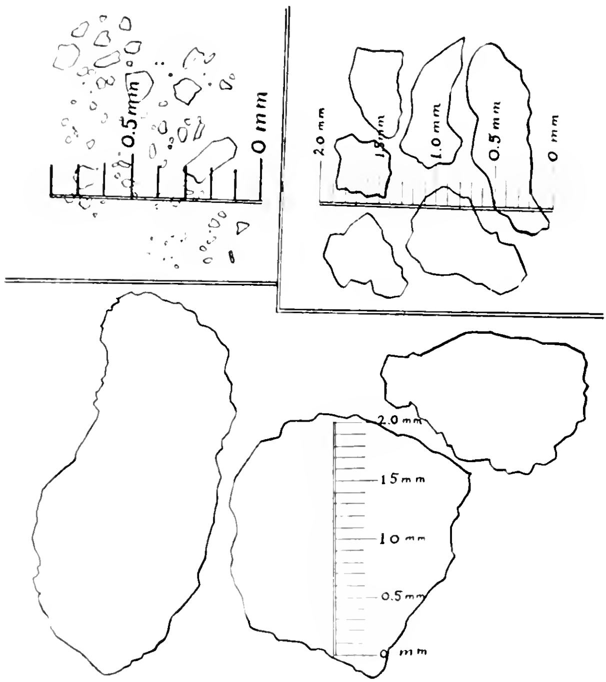

Fig. 1.

This does not mean, however, that decomposition in the drier soils must remain incomplete. As long as the moisture film is sufficiently coherent to allow diffusion from one soil particle to the other, the decomposition will be complete, only a long time will be required to do this. The endpoint of bacterial decomposition will be the later, the thinner the moisture film. The data of Table VI show quite conclusively that the decomposition in the moister soils is faster in the beginning, but soon comes to a stop, while the drier soils work slowly and steadily, and finally are ahead of the moister samples. The oxygen in the moist samples is soon exhausted and is replaced very slowly if at all. In the drier soils, the diffusion of food to the cells is slow, but constant, and the oxygen supply is sufficient to decompose all available food. The Series III and IV especially show this very plainly. In both series, there are two soils, each with and without fertilizer, at

15 and 25% moisture. In each of these eight examples, the decomposition at 15% moisture is slower in the beginning, and higher in the end than at 25% moisture. Table VIII gives the averages of these eight sets, computed in various ways. The comparison of the rate of ammonia-formation in the middle section of the table shows the interesting fact that in the last 10 days, the drier soils form about twice as much ammonia per day as the moist ones. Indeed, it seems quite doubtful that the dry soil have really reached the endpoint.

The lower section of the table shows how many per cents of the total ammonia are produced in the different time intervals. The result can be summarized in the statement that the dry soils produced 38% and 40% of the total ammonia in the first 6 days while the moist soils produced 69% and 67% in the same time.

TABLE VIII.

Ammonia Produced in the Average of four Soils at Various Moistures.

	Moisture.	2 days.	4 days.	6 days.	10 days.	20 days.
Unfertilized	15%	13.5	45.9	61.6	97.4	169.4
	25%	24.0	50.3	91.7	98.3	131.6
Fertilized	15%	25.3	68.0	96.1	151.5	212.3
	25%	35.9	68.7	14.2	129.4	169.5
Daily Ammonia Production.						
Unfertilized	15%	6.8	*16.2*	9.4	8.2	7.2
	25%	12.0	13.2	*20.7*	1.9	3.3
Fertilized	15%	12.7	*21.4*	14.1	14.6	8.8
	25%	18.0	16.3	*22.8*	4.0	4.0
Per cents of Total Ammonia Produced at Different Intervals.						
Unfertilized	15%	8%	19%	11%	19%	43%
	25%	18%	20%	31%	15%	25%
Fertilized	15%	11%	18%	11%	24%	36%
	25%	21%	19%	27%	9%	24%

The retardation through too thin surface films is also quite evident in the Series VI of the experiments (Table VI) where coarse, medium and fine sand are compared. At the same moisture content, the coarse sand has the thickest surface film, and should therefore show the most rapid decomposition in the beginning. The first section of Table IX proves this point quite conclusively. The fastest decomposition in the coarse sand is during the first two days, in the medium sand, it is best during the second and third day, and the maximum for the fine sand is between the fourth and sixth days.

TABLE IX.

Daily Average of Ammonia (mg per 100 cc.) produced by B. mycoides in various sands.

	0-2 days.	2-4 days.	4-6 days.	6-11 days.	11-21 days.
Coarse sand	*39.5* mg	6.3 mg	9.6 mg	9.8 mg	1.8 mg
Medium sand	*21.0*	*20.0*	13.7	7.4	1.1
Fine sand	9.0	6.1	*13.0*	0.6	1.0

Daily amount of ammonia produced by B. mycoides in the same sand with various moisture contents.
(mg per 100 cc.)

	Moisture.	0-2 days.	2-4 days.	4-6 days.	6-11 days.	11-21 days.
Coarse sand	10%	*53.5*	10.7	35.3	3.0	3.7
	20%	*24.5*	2.6	15.6	3.8	0.5
Medium sand	10%	21.4	*36.7*	26.0	9.8	2.1
	25%	*12.2*	9.2	6.1	7.5	0.4
Fine sand	15%	7.7	3.9	*23.2*	0.8	1.0
	30%	*15.6*	6.0	5.9	0.6	0.9

Per cents of total Ammonia Produced at Different Intervals.

	0-2 days.	2-4 days.	4-6 days.	6-11 days.	11-21 days.
Average:					
Dry	26%	16%	*35%*	11%	12%
Moist	*31%*	16%	22%	21%	9%

The second section of Table IX compares the daily ammonia formation in each sand at the highest and lowest moisture content. The maximum rate of decomposition in the coarse sand is within the first two days, regardless of the moisture content. In the medium sand, the moisture content causes a difference; the drier soil has the maximum after two days, the moister soil before two days. In the finest sand, the difference is still more pronounced, the moist sand having its maximum in the first two days, while the drier sand does not show this until after 4 days.

The last section indicates what percentage of the total ammonia was formed in the various time intervals. The results agree with the above conclusions. The averages show that the largest amount of ammonia in the moist sands is formed in the first two days, while in the drier sands, it is formed at about the fifth day.

The endpoint of decomposition will be influenced by drying if the moisture film is interrupted and does no more allow a diffusion from one particle to the other. In this case, the distribution and number of bacteria play the deciding rule. A sand with 1 mm. grainsize contains about 700 particles per gram; 0.1 mm. grainsize gives 700,000 particles, and 0.01 mm. grainsize 700,000,000 particles per gram of soil. In fine soils, only part of the soil particles will have bacteria, while others will be sterile. If, in this case, the moisture film does not allow diffusion from one particle to the other, the endpoint will depend upon the number of cells in the soil.

Influence of Ventilation. It has been stated in several places that the enormous increase of ammonia production in sand cultures is due to the increased oxygen supply which is regulated by the ventilation of the soil. The ventilation, or permeability to air, of dry soil is proportionate to the square of the grain diameter, according to King. Mathematical relations between moisture content, grainsize and permeability are not known to the writer. It is safe to assume, however, that with the same moisture content, the increase of grainsize increases the per-

meability very much. Naturally, the air surrounding the soil particles will never contain more oxygen than the air over a peptone solution. If the bacteria in a sand culture find more available oxygen than in a plain solution, this is the result of a faster gas exchange. This exchange depends entirely upon the surface exposed and upon the oxygen concentration in the liquid and the gas phase. The amount of oxygen in the soil air depends directly upon the ventilation. But the surface between liquid and gas, or the depth of the liquid, is also very essential. The culture in peptone solution in a layer about 2 cm. deep produced in two days 2.7 mg NH_3 (Table VII); the same culture spread over sand in a layer about 20 μ deep, produced in the same time 79.5 mg NH_3; in the latter culture, the surface between gas and liquid was approximately a thousand times larger than in the former, while all other conditions were practically identical. The oxygen concentration in a sterile solution is the same whether it is spread over soil or sand particles or in a flask by itself. After inoculation, the bacteria begin to use up the dissolved oxygen and the further growth of obligate aerobic bacteria depends upon the rate of oxygen replacement. If the oxygen-content of the air remains constant, the oxygen replacement is in direct ratio to the surface, or in invert ratio to the depth of the liquid.

Even the decrease in the depth of liquid from 30 μ to 20 μ (medium sand with 15% and 10% moisture) yields an increase of ammonia (see Table VII). A further decrease of the depth to 10 μ (5% water) results in a decrease of ammonia. This has been explained in the former paragraph by the too slow diffusion of the food in the very thin films. The most abundant oxygen supply is of no benefit to the cells if they have no food to be oxidized.

It must be remembered that the oxygen supply does not depend solely upon the contact surface between liquid and gas, but also upon the oxygen concentration in this gas. The oxygen of the soil air will be used up very fast, and the further development depends entirely upon the ventilation. If there is no ventilation, the growth of strictly aerobic bacteria will cease as soon as the last trace of oxygen is used up, regardless of the film thickness.

It should be pointed out briefly how little oxygen is actually available to aerobic microörganisms in our ordinary liquid media in flasks or test tubes. For experiments concerning the actual oxygen requirements of microörganisms, it seems necessary to use sand cultures rather than the customary liquid cultures, because only in this way an even oxygen concentration can be secured.

The best conditions of existence for *B mycoides* in sand of 1 mm. grain diameter were found to be at about 10% moisture, i. e. at a moisture film of about 20 μ thickness. A soil or sand with 0.5 mm. grainsize would require 20% moisture to give the optimal moisture film. If the grainsize is 0.1 mm., the moisture necessary to produce the optimum film thickness would be 100 parts of water to 100 parts of dry soil. Such soil is, of course, water-logged and has no ventilation whatever. Most agricultural soils have a grainsize nearer 0.1 mm. than 1.0 mm. The consequence is that in these soils, the strictly aerobic bacteria can never have optimal conditions of existence. If the oxygen supply is sufficient, the food-supply is inadequate on account

of the too thin moisture film, and if the moisture films are thick enough to supply the food, the soil solution prevents the ventilation and gas exchange entirely. The growth of aerobic bacteria in fine-grained soils is a compromise. Table VI proves that this condition actually exists. The highest ammonia production was obtained in the sand cultures, and not in the soils, though these contained a good many valuable food compounds. The soil extracts range higher than the peptone solutions, but the sand cultures are distinctly superior to the soil cultures.

It can be deducted from the discussions of this chapter that the optimal conditions for aerobic bacteria in soil are an appropriate moistrue film (approximately 10 — 20 μ) and the greatest possible ventilation. Consequently, the life conditions will improve with increasing grainsize, because the ventilation increases with the square of the grain diameter, the water film in direct ratio with it. In agricultural soils, there is no danger that the moisture film becomes too thick from increase of grainsize. Only if the grainsize exceeds 2 mm., this condition is apt to take place, and such soils are not used for agricultural purposes. It is therefore safe to state the following: *Life conditions for aerobic bacteria improve with increasing grainsize of the soil.*

The influence of the water content cannot be stated in such a general way. For agricultural soils of a grainsize less than 0.5 mm, the moisture film should be as thick as possible and still allow good aeration. Definite statements concerning the relation between bacterial development, grainsize and moisture content cannot be made until a mathematical formula has been found for the dependence of ventilation from grainsize and moisture content.

II. THE ENDPOINT OF FERMENTATION.

It has been generally assumed in the preceding pages that the greatly increased ammonia formation in the sand cultures is due to an increased oxygen supply. It remains to explain the biochemical mechanism of this stimulating action of the oxygen. The endpoint of a fermentation is ordinarily considered to be due to either the accumulation of harmful products or the lack of food. In these experiments, lack of food cannot figure as an explanation since less than 20% of the total nitrogen in peptone is changed to ammonia. Accumulation of harmful products should then be the other alternative. Yet, it seems highly improbable that bacteria in quartz sand can tolerate 6 to 8 times as much ammonia as in solution. An adsorption of ammonia by the sand to such an extent would contradict all experience.

Endpoint and Number of Bacteria.—In a previous paper* the author has found certain lactic bacteria to grow faster and produce more acid in the presence of peptone. This was explained by the theory of an equilibrium between the zymase in the cells and the acid produced. An increase in the number of cells meant an increase in the zymase, and this caused a disturbance of the equilibrium resulting in more acid formation. Possibly this theory would explain the ammonia increase. The abundant oxygen supply might cause a greatly increased growth, and the consequent increase of ammonia-forming enzyme would result in

*Michigan Agricultural College Technical Bul. No. 10 (1911) p. 30.

a continued ammonia formation. The increase in cells would have to be very large, for the three to five fold number of lactic bacteria caused only a doubling of the acid, and here we are dealing with an increase of 6 to 8 times the original amount of ammonia.

For the experiments with counting bacteria, *B. mycoides* was not considered a suitable organism, because such thread bacteria do not allow of great accuracy in plating. Three pure cultures of bacteria were isolated for this purpose from putrefying peptone solution. They were ammonia producers and formed an even cloudiness without scum in liquid media; the species names were not determined. The technic of their culture varied from that of the first experiment. The actual medium was a 1% solution and this medium was used as such, and mixed with sand in two proportions: 100 g. of sand (medium quartz) + 50 cc. solution and 200 g. of sand + 20 cc. of solution. Thus, there were three conditions established, the solution, the water-logged soil (the liquid stood a few millimeters over the sand) and the well-aerated soil. The bacteria were counted on agar plates, each number representing the average of two counts from the same sample. The experiments were carried out by Mr. A. Itano and Mr. Eugene Brown. The ammonia is computed per 100 cc. of solution, the bacteria per cc.

The results are, on the whole, not satisfactory. The counts in Exp. X were so unsatisfactory that they are entirely omitted. All three sets of data show the same general occurrence: increased number of cells as well as increased ammonia formation in the well aerated sand cultures. The increase in the numbers is not high enough, however, to account for the ammonia increase.

TABLE X.

Milligrams Ammonia in 100 cc. of Peptone solution.

	A. 100 cc.	B. 100 cc. + 200 sand.	C. 100 cc. + 1000 sand.
After 24 hours	2.55	7.99	8.50
After 48 hours	6.29	8.16	18.28
After 72 hours	7.65	9.52	21.25
After 96 hours	9.86	11.90	61.62
After 120 hours	11.22	13.09	65.87
After 144 hours	12.75	14.79	72.25
After 168 hours	14.28	17.51	77.35

TABLE XI.

Age.	A.		B.		C.	
	Solution.		100 sol. + 200 sand.		100 sol. + 1000 sand.	
	mg NH_3	bact. per cc.	mg NH_3	bact. per cc.	mg NH_3	bact. per cc.
Beginning	0	910	0	910	0	910
After 24 hours	1.53	9,500,000	2.38	8,400,000	4.68	28,200,000
After 48 hours	7.48	12,500,000	10.03	28,000,000	23.38	180,000,000
After 72 hours	8.67	20,000,000	10.05	17,000,000	37.40	342,000,000
After 96 hours	12.92	37,000,000	16.66	17,000,000	47.60	312,000,000
After 168 hours	20.57	28,000,000	21.93	26,500,000	62.48	282,000,000

TABLE XII.

Age.	Solution.		100 sol. + 200 sand.		100 sol. + 1000 sand.	
	mg NH_3	bact. per cc.	mg NH_3	bact. per cc.	mg NH_3	bact. per cc.
Beginning	0	8,200	0	8,200	0	8,200
After 24 hours	0.85	19,000	1.53	13,980,000	5.10	35,880,000
After 48 hours	1.70	30,000	lost	26,200,000	18.28	290,400,000
After 72 hours	1.70	120,000	3.91	45,900,000	26.35	325,200,000
After 96 hours	3.06	84,000,000	5.44	36,600,000	33.58	510,000,000
After 192 hours	6.80	155,000,000	....	....	52.70	120,000,000

Endpoint and adsorption.—The tables X-XII show one rather interesting point, namely the ammonia in the saturated sands. This seems rather strange since the conditions in the saturated sand are more strictly anaerobic than in solution. The sand is a mechanical obstacle to the diffusion of oxygen into the deeper layers, and prevents also the currents which help to distribute oxygen through liquids. The explanation through air held mechanically by the sand does not hold true because exactly the same is true with *Bacterium lactis acidi* (see Tables XIX-XXII). These would be retarded by the presence of oxygen, but they develop better in sand saturated with milk than in milk alone.

These data have a certain similarity with the finding of plant physiologists, that the toxic action of certain poisons is reduced or even disappears entirely through the addition of such finely divided materials as quartz sand, filter paper or paraffin. The explanation given is generally adsorption, though in no case the decrease of poison in the solution has been proved by analysis.

Gibbs determined with a few minerals salts the amounts actually adsorbed by quartz sand, and found it in some cases to be unmeasurable, in others to be less than 1 mg per square meter of surface. This speaks very plainly against any explanation of the high ammonia yields in the well-aerated soils while it might suffice for the difference in solution and water-logged sand.

Endpoint and Ammonia Concentration. All these experiments make it seem rather doubtful whether the growth of *B. mycoides* is actually limited by the accumulation of ammonia or rather ammonium carbonate. If this were the case, one would have to conclude necessarily that in sand the bacteria can tolerate 8 times as much ammonia as in solution. The tolerance for ammonium carbonate can be easily tested. A standard solution of ammonium carbonate was pasteurized at 80 C. for half an hour, and was then mixed with a sterile peptone solution in certain proportions. After repeated inoculation, *B. mycoides* was found to grow in the presence of 200 mg NH_3 per 100 cc. If, therefore, the decomposition of peptone solution ceases at 23 mg NH_3 per 100 cc., this is not due to the accumulation of ammonia.

Endpoint and Oxidation.—The previous experiments establish the facts that the ammonia formation by *B. mycoides* is not comparable to the acid or alcohol formation by other microörganisms. The neutralization of acid, the removal of alcohol allow a new development of the organisms, consequently they are inhibiting products. The ammonia

is no such "autotoxic" metabolic product. This puts the entire ammonification experiments upon a new basis.

Since the ammonia must be considered a metabolic product of secondary importance, it was thought possible to explain its formation as the remainder of an oxidizing process of the peptone molecule. The nitrogen atoms in the peptone molecule are doubtless present in various combinations. There are very probably amino-groups, imino-groups, acid-amid-groups and substituted amids. It is not unreasonable to assume that some of these groups can be split by hydrolysis liberating ammonia, while others cannot. It is worth while to call attention to the experiments of Shibata* with the "amidase," an ammonia forming endo-enzyme of *Aspergillus niger.* This amidase produced ammonia from urea, biuret and certain acid-amids, but not from mono-amino-acids. The enzyme is evidently hydrolytic, and is able to hydrolize only when the NH_2 group and oxygen are at the same carbon atom, as is the case in acid-amids, urea and biuret, but not in amino-acids.

$$R - CONH_2 + HOH = RCOOH + NH_3.$$

It seem then that the nitrogen atoms of the amino and imino-groups are not ammonified by hydrolysis. If this be not possible, ammonia can be liberated only through the destruction of the entire molecule by oxidation, as may be illustrated with amino-acetic acid:

$$NH_2CH_2CO_2H + 3O = NH_3 + H_2O + 2\ CO_2$$

Such oxidation will take place much more freely in a sand culture than in a solution, and it is quite easily understood that a more complete oxidation of the peptone will cause a more complete ammonification of the nitrogen. The ammonia would then be an incidental product, nothing but an indigestible piece of an otherwise digestible molecule.

This explanation of the "high endpoint" of ammonia formation can be considered proved, if the increase of ammonia can be shown to be accompanied by an increased production of CO_2. This was done in the following experiment which was carried out by Mr. H. K. Wright.

The cultures were kept in flasks with ground glass stoppers which were perforated by two glass tubes, one opening near the bottom of the flask, the other one just allowing gases to escape. The cultures were grown in 25 cc. of a 5% peptone solution, and in 50 g. of medium sand + 5 cc. of peptone solution. Every 24 hours, free air was drawn through these flasks for 20 minutes, and the air, after passing a small wash bottle with n/10 H_2SO_4 and a $CaCl_2$ tube, left the CO_2 in a potash-bulb, which was weighed daily. On the twelfth day, sulfuric acid was put into the cultures to liberate the CO_2 which was chemically bound to the ammonia; after this, the ammonia was determined. The results of Table XIII prove the theory.

About 15% of the total ammonia of the sand cultures was found in the small wash bottles.

*Hoffmeisters Beitrage Band 5"(1904) p 384.

TABLE XIII.

CO_2 Formation from Peptone by B. mycoides in Sand and Solution.

	mg. CO_2 per flask.				Average CO_2 per 100 cc. liquid medium.	
	25 cc. solution.		5 cc. solution + 50 g. sand.		Solution.	Sand.
	a.	b.	c.	d.	a + b	c + d
After 1 day	0.	0.	0.2	7.4	0	76
After 2 days	3.2	0.4	9.0	18.8	7	278
After 3 days	5.0	1.4	17.6	27.8	13	454
After 4 days	(2.6)	(0.6)	22.4	34.4	....	568
After 5 days	3.9	2.0	32.0	44.5	12	765
After 6 days	7.8	7.3	44.8	60.8	30	1,056
After 7 days	8.0	10.5	50.8	63.8	37	1,146
After 8 days	8.8	11.8	57.8	73.7	47	1,315
After 9 days	11.4	21.1	66.0	82.4	65	1,484
After 11 days	13.0	....	70.2	87.5	....	1,577
After 12 days	16.4	35.0	73.6	90.2	103	1,638
CO_2 liberated on 12th day by H_2SO_4	5.8	11.2	11.9	13.7	34	256
Total CO_2 formed	22.2	46.2	85.5	103.9	137	1,894
mg. Ammonia found	10.95	15.92	15.30	15.91	54	312

Most experiments in this chapter would have been omitted if the writer had found in time the paper of Emil Marchal on ammonification.* This paper discusses very extensively the ammonia formation by *B. mycoides* in albumen solution. Marchal concludes (p. 589 and 590): "When a simultaneous estimation is made of the carbonic acid and ammonia produced by the respiration of the microbe, it is found that the proportion of these substances obtained, closely approximates that which is obtained by the complete combustion of albumen." The ratio obtained was 1:8.9 while the combustion gives 1:10.4. Marchal comes to the following conclusion: "Under the influence of *B. mycoides*, oxygen acts on the elements of albumen, the carbon being transformed into carbonic acid, the sulphur into sulfuric acid, a part of the hydrogen into water, while ammonia is left as a residue."

Marchal tried further the influence of aeration by growing the bacteria in equal volumes of liquid, the depth of the liquid being 12 cm., 5 cm., and 2.5 cm., respectively. The ammonia formed in these three experiments was 16.8, 34.0 and 50.0 mg. per 100 cc. in 15 days.

The ratio of $NH_3 : CO_2$ in the writer's experiment is 1:2.5 in the solution and 1:6.1 in the sand, while the theoretical yield of a complete combustion, figuring on 46.1% C and 13.8% N in Peptone Witte, according to our determinations, is 10.2. The circumstance that the CO_2 produced per one part of ammonia liberated is much less in solution,

*Bull. de l'Academie Belgique t. 25, (1893) p. 727 translated into English in Agricultural Science Vol. VIII, p. 574.

is easily explained by the very probable assumption that certain nitrogen atoms can be split off from the peptone molecule by hydrolysis, i. e. without simultaneous formation of CO_2, while the bulk is liberated only if the adhering organic radicals are oxidized.

III. EXPERIMENTS WITH OTHER AEROBIC BACTERIA.

The experiments in the preceding pages have been carried on exclusively with bacteria liberating ammonia from peptone which was found to be a process of complete oxidation. It is probable that other strictly aerobic bacteria will behave similarly in soil, because with them, also, the oxygen supply is the regulating factor. Bacteria requiring much oxygen, such as the vinegar bacteria, require a very thin moisture film to accelerate the oxygen exchange as much as possible. The bacteria which require oxygen for their energy supply will all belong to this group. But there are other aerobic bacteria obtaining their energy from nonoxidative processes, and requiring oxygen for life, such as the urea-fermenting organisms. The amount of oxygen used by these organisms is very small, and the replacement of oxygen will be much less important to them than to the vinegar bacteria. Bacteria of this type should hardly be influenced at all by the ventilation and by the presence of sand and the exposed surface, except that too thin a moisture film must prevent the ready food supply, and consequently retard the entire metabolism. The following pages give three examples of aerobic bacteria acting upon various compounds.

Azotobacter in Sand and Solution.—The Azotobactor species are know as strictly aerobic bacteria. Krainsky* determined the amount of CO_2 produced by a pure culture of *Azotobacter* in sand with 5, 15 and 20% moisture. He computed his data per 500 g. of sand, but he compares mainly the relation of CO_2 to the amount of nitrogen fixed. From his data can be compiled the following table:

TABLE XIV.

Azotobacter in Mannit-Solution + Sand. (All data per 100 cc. of Solution.)

Moisture content.	5%	15%	20%
mg CO_2 formed in 18 days	668	1,214	986
mg C oxidized	182	331	268
mg N fixed	16.48	11.46	9.78
N : CO_2	1:41	1:106	1:99
N : C	1:11	1:29	1:28

The nitrogen fixed by young cultures of *Azotobacter* may be considered proportionate to the number of cells. Under this supposition, it can be stated that the bacteria grew best at 5% moisture, and used the carbon source most economically. Since Krainsky does not mention the grainsize of the sand, it is not possible to make any computations concerning the moisture film. Nothing can be said even concerning the optimum moisture because there are no data to fill the gap between 5 and 15% moisture.

One little experiment concerning the nitrogen fixation of an *Azo-*

*Centralbl. f. Bakt. II, Bd. 26 (109) p-231.

tobacter species has been made by Mr. A. Itano. The general outline of experiments corresponding to the experiments X, XI, XII. The nutrient solution, a solution of 2% dextrose and 0.02% K_2HPO_4 in tap water, was used as such and mixed with medium sand in the proportions 20 : 200 and 50 : 100. The sterilized media were inoculated with a pure culture of a freshly isolated *Azotobacter* species and the total nitrogen was determined after 7 weeks.

TABLE XV.

Nitrogen fixation of Azotobacter in Sand Cultures. (mg N per 100 cc. solution).

Medium.	Single determinations.				Average.
100 cc. solution	4.2 mg	4.2 mg	4.2 mg	2.8 mg	4.3 mg
100 solution + 200 sand	6.3 mg	5.6 mg	5.6 mg	4.9 mg	5.6 mg
100 solution + 1000 sand	38.5 mg	35.0 mg	35.0 mg	31.5 mg	35.0 mg

The results agree entirely with all those of the previous experiments. There is the same great increase of bacterial development of about 1000% in the well ventilated sand over the plain solution, and the water-logged sand is again a little superior to the solution without sand. The amount of sugar used up has not been determined.

Vinegar Bacteria in Sand and Solution.—As a further representative of a strictly aerobic organism, the vinegar fermentation was used.

The experiment was carried out as follows: The nutrient solution was cider + 8% alcohol, which was pasteurized for 2 hours at 80° and was then inoculated with a young pure culture of a vinegar bacterium which is used as a vinegar starter. This inoculated cider was distributed with sterile pipettes into flasks containing each 100 g. of sterile sand (medium quartz sand). The various mixtures, and the amounts of acid formed by them at different times, are given in Table XVI. The table shows only the acid actually produced, i. e. after subtracting the acidity of the cider, in grams per 100 cc. of solution. The data are averages from duplicate determinations.

TABLE XVI.

Acetic Acid formed from Alcohol in Sand and Solution.

Culture.	1 days.	10 days.	17 days.	24 days
5 cc. + 100 g Sand	0%	0.41%	0.28%	0.12%
10 cc. + 100 g Sand	0%	1.55%	0.47%	0.35%
15 cc. + 100 g Sand	0%	3.91%	2.30%	0.75%
20 cc. + 100 g Sand	0%	4.67%	4.02%	3.33%
25 cc. + 100 g Sand	0%	1.30%	4.55%	3.80%
30 cc. + 100 g Sand	0%	0.60%	4.90%	4.90%
50 cc. + 100 g Sand	0%	0.	0.09%	4.73%
75 cc. + 100 g Sand	0%	0	0.	0.23%
100 cc. + 100 g Sand	0%	0.	0.	0.05%

The experiment does not show the emphasized point very well because the vinegar bacteria destroyed again the acid which they originally formed. This destruction is a complete oxidation and like all oxidations takes place fastest in the driest sand. After 10 days, when the sand with 5% moisture shows hardly any acid, the sand with 20%

moisture is at the height of its acidity, while the sand with 20% moisture is just getting started. The actual efficiency of these bacteria can be estimated only if CO_2 and CH_3CO_2H are both determined.

It would be absolutely wrong to conclude from the above table that the optimum conditions prevail at 20 — 30% moisture. One should rather conclude that under these conditions the oxygen supply is not sufficient to allow complete oxidation of the food, and therefore, the acetic acid accumulates. This is the ideal condition for the vinegar manufacturer, but not for the bacteria themselves. They would be much better off if they could dispose of the noxious acid by changing it into the volatile carbon dioxide. For such oxidation, the sand cultures with 5 and 10% moisture afford much better opportunity.

Urea Bacteria in Sand and Solution.—The urea-fermenting bacteria differ from the previously mentioned bacteria by the circumstance that they can provide for their energy by hydrolysis, without using oxygen. However, they are aerobic bacteria and cannot live in the entire absence of oxygen. They need the oxygen probably for some process in cell construction, and this amount is so small that for some time, they were considered to be facultative anaerobic.

The arrangement of the experiment was similar to the preceding. The nutrient medium was a solution of 5% of urea and 0.2% of citric acid. To 1.5 liters of this was added 20 cc. of bouillon. The culture used which was not pure, was obtained by putting soil into a little of the above solution until fermentation started, and then transferring several times in the same medium. The urea solution was inoculated heavily with this culture containing an accumulation of bacteria. The medium was then transferred by means of sterile pipettes into flasks containing each 100 g. of sterile sand. The ammonium carbonate was determined by diluting and titrating aliquot portions with tenth normal acid and methyl orange. The experiment was carried out by Mr. H. K. Wright.

TABLE XVII.

Urea Fermentation in Sand and Solution.

(Per cents of $(NH_4)_2CO_3$ per 100 cc. of solution.)

	3 days. (%)	10 days. (%)	12 days. (%)	16 days. (%)	23 days. (%)	28 days. (%)
100 g Sand + 5 cc solution	0	0.13	0.17	0.27	0.31	0.25
100 g Sand + 10 cc solution	0	0.49	0.11	0.27	0.24	0.20
100 g Sand + 15 cc solution	0	0.59	0.50	0.21	0.	0.
100 g Sand + 20 cc solution	0	1.17	0.65	0.23	0.33	0.
100 g Sand + 25 cc solution	0	0.53	0.62	1.78	0.32	0.
100 g Sand + 30 cc solution	0	0.40	0.99	1.02	0.26	0.
100 g Sand + 50 cc solution	0	1.08	1.19	1.40	2.34	2.55
100 g Sand + 100 cc solution	0	0.05	0.38	1.84	2.43	2.60

The agreement of the data is not satisfactory because of the inaccurate method of analysis and of the evaporation of ammonia in the drier samples. Perhaps the fact that no pure culture was used, also influenced the results. It can be concluded with certainty, however, that the optimum conditions are not at 10% moisture, but over 20%.

One could perhaps conclude that the sand has practically no influence, except that it prevents fast development in the drier samples. A more conclusive experiment with a real pure culture could not be made for lack of time.

IV. LIFE CONDITIONS FOR ANAEROBIC MICROÖRGANISMS IN SOIL.

After the previous discussions, the conditions for anaerobic development can be foretold to some extent. The situation is simply that changes of the moisture film will influence anaerobic and aerobic bacteria in the same way, the effect being entirely of physical nature, while the changes due to aeration will have the reverse effects upon anaerobes. The deductions are, therefore, the following:

1. The thicker the moisture film, the better the growth. The thickness of the moisture film increases with grainsize and moisture content.

2. The less aeration, the better the growth. Aeration decreases with with decreasing grainsize and with increasing moisture. The differences between aerobic and anaerobic organisms in soils are this: Aerobic bacteria are, under all circumstances, favored by a large grainsize, because it increases the thickness of the moisture film as well as the aeration. The moisture content, though necessary in a small degree, reduces aeration very much and is by no means of unlimited benefit. Anaerobic bacteria are, under all circumstances, favored by moisture, because it increases the moisture film and, at the same time, reduces aeration. Increase of grainsize increases the aeration faster than the thickness of the film, so that one might be led to believe a small grainsize most favorable. However, another feature has to be considered. A thin moisture film, which is necessarily the result of a small grainsize not only retards the food supply, but at the same time, favors the oxygen supply. It must be kept in mind, further, that the anaerobic bacteria use practically no oxygen at all, and therefore the ventilation, or oxygen exchange, is of no importance. The oxygen present in the soil is the retarding factor, its replacement is unnecessary since it does not disappear. Therefore, the most important thing for anaerobic bacteria is the thick moisture film, and this increases with the grainsize. Consequently, a large grainsize is most favorable for pure cultures of anaerobic bacteria.

Alcoholic Fermentation.—An experiment illustrating this point has been carried on as early as 1885 by Soyka*. His solid medium was glass beads, 0.54 mm. in diameter, his organism was *Saccharomyces cerevisiae*, his medium a sugar solution, the composition of which is not given in the abstract. The yeast inoculum was varied from 5% to 17% of the liquid. The fermentation was carried on for 12 hours, and the results of the analysis are given as "fermented sugar in per cents of total sugar."

*Quoted after Handbuch der Hygiene (Pettenkofer und Ziemssen) 1887. Erster Teil, Zweite Abteilung, 3 Heft: Der Boden, von Soyka; p. 227.

TABLE XVIII.

Alcoholic Fermentation of a Sugar Solution with Glass Beads.

Solution.	Glass beads.	Moisture in per cent.		Sugar fermented.			Contact surface solid to liquid.
		of weight.	of pore space.	5% yeast.	11.4% yeast.	17% yeast.	
10 cc.....	0	100%	....	50–53	75.6	89.3	circ 8 sq. cm.
10 cc.....	33.0	23%	150%	56.6	*86.0*	87.5	1,300 sq. cm.
10 cc.....	49.5	17%	100%	*65.6*	83.9	*93.0*	2,000 sq. cm.
10 cc.....	62.0	14%	80%	56.2	78.6	*93.0*	2,500 sq. cm.
10 cc.....	99.0	9%	50%	37.5	57.0	*93.0*	4,000 sq. cm.
10 cc.....	165.0	5%	30%	37.5	57.0	76.0	6,600 sq. cm.
10 cc.....	247.0	4%	20%	30.5	36.0	71.0	9,900 sq. cm.
10 cc.....	495.0	2%	10%	0.	28.6	63.6	19,800 sq. cm.
10 cc.....	990.0	1%	5%	0.	0.	32.4	39,600 sq. cm.

The inoculum in this experiment is so large that multiplication can be neglected. The active mass in the three different series was approximately 1:2:3. The maximum fermentation was found to take place in the water-saturated "soil," at 100 to 150% of the pore space. That the water-saturated soils are a better medium for anaerobic organisms than liquids without sand, has been discussed in the previous chapter (p. 34).

The grainsize being constant, the fermentation is entirely regulated by the moisture content. Decrease of moisture will decrease the film diameter and increase the aeration, both unfavorable for the anaerobic fermentation by yeast. The result must be a continuous decrease of fermentation with decreasing moisture. The data prove this to be the case in every instance.

The influence of the inoculum is surprisingly large. The time being limited to 12 hours, the data can by no means be regarded as end-points. Otherwise, the data in all water-saturated soils should be the same in all three series. But that, at 2% moisture, an increase of inoculum from 5% to 17% causes an increase of decomposition from 0 to 63% seems rather incredible. Since nothing is said concerning the method of inoculation or analysis, it is impossible to find whether and where there was a chance for a mistake. The moisture film at 1% moisture is 2.5 μ, i. e. smaller than the diameter of the yeast cell.

Bacterium lactis acidi in Sand and Solution.—Original experiments concerning the development of anaerobes in soil were carried on only with *Bacterium lactis acidi*. Though this bacterium is not strictly anaerobic, it is decidedly favored by anaerobic conditions, and the fact that it is able to grow under aerobic conditions to some extent is more an advantage than disadvantage in these experiments. Especially the methods of handling and counting these organisms are greatly simplified since no precautions have to be taken to avoid contact with oxygen.

The first experiment was carried on with Strain II* of this laboratory. Four different series were made, A, milk in deep layer, B, milk in shallow layer (about 4 times as large a surface), C, 50 cc. milk in 100 g. of medium quartz sand (the milk stood a few millimeters over the sand) and D, 20 cc. milk in 200 g. sand which mixture allowed a good aera-

*Concerning the properties of the two strains, see Mich. Agric. Coll. Expt Sta. Technical Bul. 10

tion. The whole arrangement corresponds to the experiments of Tables X, XI, XII. Table XIX gives the acidity in degrees, and the numbers per cc. of liquid.

TABLE XIX.

Bact. lactis acidi (Strain II) in Milk with and without Sand.

Age.	A.		B.		C.		D.	
	Milk, deep.		Milk, shallow.		100 milk + 200 sand.		100 milk + 1000 sand.	
	Number.	Acid.	Number.	Acid.	Number.	Acid.	Number.	Acid.
0 hours.....	490,000	11°	490,000	11°	490,000	11°	490,000	14°
18 hours......	535,000,000	56°	562,000,000	55°	890,000,000	68°	248,000,000	28°
24 hours......	251,000,000	70°	409,000,000	67°	900,000,000	72°	528,000,000	50°
42 hours......	....	77°	....	78°	....	82°	....	62°
72 hours......	....	90°	....	88°	....	96°	....	64°

The variation in the first two samples is within the limits of error, and it may be stated safely that a fourfold increase of surface has practically no influence upon this strain. In the last column, sand + 10% milk, the surface is increased approximately 1000 times, and the result is a distinct retardation of growth and acid production, especially in the beginning. The milk-saturated sand was the best medium, because it afforded more strictly anaerobic conditions than the milk, and besides, the absorption may exercise a helpful influence.

To study the rôle of the moisture film, two larger experiments were carried out which are really duplicates of the above with coarse, medium and fine sand. The milk in shallow layer was omitted. Since the plating and titrating required a good deal of time, each experiment was divided into two sections which were carried one hour apart with separate checks. For all data which are compiled in Tables XX and XXI, I am obliged to Mr. A. McVittie.

TABLE XX.

Strain II of Bacterium lactis acidi.

Hours.	Milk alone.		50 cc. of milk + 100 gr. of sand.					
			Coarse sand.		Medium sand.		Fine sand.	
	Bacteria per cc.	Acidity.	Bacteria per cc.	Acidity.	Bacteria per cc.	Acidity.	Bacteria per cc.	Acidity.
0	700	17.0° 17.5°	700	17.0° 17.5°	700	17.0° 17.5°	700	17.0° 17.5°
16	1,300,000,000 1,320,000,000	62.5° 63.0°	924,000,000 1,218,000,000	52.0° 52.8°	1,320,000,000 1,560,000,000	61.2° 61.2°	1,488,000,000 1,728,000,000	62.0° 62.8°
24	1,470,000,000 1,620,000,000	73.0° 73.0°	2,040,000,000 2,680,000,000	75.2° 75.2°	1,592,000,000 1,618,000,000	78.0° 78.4°	1,704,000,000 1,720,000,000	74.0° 76.0°
40	1,580,000,000 1,760,000,000	81.5° 82.0°	1,300,000,000 1,424,000,000	91.2° 91.2°	1,840,000,000 2,080,000,000	92.0° 92.0°	1,752,000,000 1,928,000,000	86.0° 86.4°
88	....	91.0° 91.0°	....	100.0° 102.0°	....	....	....	90.8° 92.0°

	Milk alone.		10 cc. of milk + 100 gr. of sand.					
			Coarse sand.		Medium sand.		Fine sand.	
0	700	17.0° 17.5°	700	17.0° 17.5°	700	17.0° 17.5°	700	17.0° 17.5°
16	1,150,000,000 1,240,000,000	63.0° 63.5°	770,000,000 800,000,000	28.0° 28.0°	1,120,000,000 1,290,000,000	32.0° 33.0°	1,360,000,000 1,410,000,000	34.0° 34.0°
24	1,670,000,000 1,680,000,000	73.0° 74.0°	940,000,000 1,020,000,000	55.0° 55.0°	1,260,000,000 1,560,000,000	57.0° 58.0°	1,500,000,000 1,630,000,000	50.0° 51.0°
40	1,680,000,000 1,720,000,000	81.5° 82.0°	1,260,000,000 1,300,000,000	71.0° 71.0°	1,580,000,000 1,780,000,000	65.0° 66.0°	1,420,000,000	54.0° 55.0°
88	....	91.0° 91.0°	....	70.0° 70.0°	....	65.0° 65.0°	....	58.0° 58.0°

TABLE XXI.

Strain IV of Bacterium lactis acidi.

Hours.	Milk alone		50 cc. of milk + 100 gr. of sand.					
			Coarse sand.		Medium sand.		Fine sand.	
	Bacteria per cc.	Acidity.	Bacteria per cc.	Acidity.	Bacteria per cc.	Acidity.	Bacteria per cc.	Acidity.
0	100,000	14.7°	100,000	15.7°	100,000	14.7°	100,000	14.7°
24	990,000,000 1,150,000,000	36.0° 36.5°	872,000,000 936,000,000	34.4° 34.4°	1,020,000,000 1,080,000,000	36.0° 36.4°	1,168,000,000 1,168,000,000	34.0° 34.8°
48	1,030,000,000 1,080,000,000	47.5° 48.5°	896,000,000 972,000,000	50.8° 50.8°	276,000,000 432,000,000	32.8° 33.2°	1,064,000,000 1,108,000,000	44.4° 44.4°
72	1,020,000,000 1,030,000,000	57.0° 57.0°	920,000,000 1,016,000,000	60.0° 60.4°	....	....	1,160,000,000 1,400,000,000	50.8° 52.8°
168	....	69.0° 70.0°	....	70.0° 72.0°	....	70.0° 71.1°	....	48.0° 48.8°

	Milk alone.		10 cc. of milk + 100 gr. of sand.					
			Coarse sand.		Medium sand.		Fine sand.	
0	100,000	14.7°	100,000	14.7°	100,000	14.7°	100,000	14.7°
25	650,000,000 916,000,000	37.5° 37.5°	416,000,000 506,000,000	24.0° 25.0°	616,000,000 732,000,000	23.0° 24.0°	690,000,000 736,000,000	14.0°
49	1,160,000,000 1,090,000,000	49.0° 50.0°	710,000,000 730,000,000	38.0° 38.0°	720,000,000 770,000,000	40.0° 41.0°	870,000,000 910,000,000	28.0°
73	1,060,000,000 1,340,000,000	55.5° 57.0°	630,000,000 670,000,000	47.0° 48.0°	710,000,000 810,000,000	43.0° 44.0°	840,000,000 930,000,000	20.0°
198	....	69.0° 70.0°	....	....	....	47.0° 50.0°	....	29.0° 30.0°

The data of the two tables confirm generally the deductions in the beginning of this chapter. Strain IV proves more sensitive against oxygen than Strain II. Both thrive best in the saturated sand of coarse and medium grain size, while the development in the fine sand is not as good. This is probably caused by the too thin moisture film. In the very beginning, the difference in the various grainsizes is not very noticeable, because there is plenty of food in the near surroundings of each cell. But when this is all used up, the food has to diffuse farther away, at the same time the acid accumulates around the bacteria. The large sized grains have large sized intervals between them, and the channels of diffusion are wide. With the small sized sand, the moisture films between the sand particles are very thin, and diffusion is slow, retarding growth and fermentation. Strain IV shows even at the last determination no probability of the fine sand finally reaching the standard of the coarser sands.

In the sands with 10% milk, the growth and fermentation is retarded in each case, and the inhibiting effect increases with decreasing grainsize. The reasons for this have been given in the beginning of this chapter. The differences between fine and medium sand are greater than between medium and coarse sand, corresponding to the greater difference in grainsize and inner surface. Some of the data do not conform with the rest, due probably to irregularities in growth or analysis. It must be remembered, too, that for each determination had to be used a separate culture.

V FINAL CONSIDERATIONS.

The experiments in this paper were undertaken with the object in view to study in what way the soil as a culture medium varies from the solution. The chemical side of this question has hardly been touched in this paper, and the physical side has been discussed only in relation to grainsize and moisture. One important phase of physical influence, namely, the humus bodies, have been omitted entirely. They are quite essential, however, on account of their spongy nature, influencing the available water. The author expects to attack this problem in the near future.

A development of these studies is possible in two directions, extending either into the chemical influences of the soil upon the bacteria or into symbiosis. The possibilities of chemical influences can hardly be all enumerated because they are so manifold. The experimental side should make no difficulties. The study of symbiotic decompositions, however, will require great experimental skill, cautious work, and very much time. Yet, it is one of the most urgent needs of soil bacteriology. Only such organisms can be tried in symbiosis whose requirements for existence are well known and whose metabolism can be followed closely by chemical analysis.

It is very evident that the results of these laboratory experiments are not directly transferable to field conditions. The statement that the coarsest grained soil will give the best conditions for aerobic bacteria is true only if the water content remains constant. A coarse-grained sand in a field will dry out so fast that bacteria find optimum conditions only for a few days during the year. Ground water changes and drainage will bring oxygen into the deeper layers of the soil occasionally, and as a matter of fact, the conditions in farming soils are changing from aerobic to anaerobic conditions continuously. It may be stated,

in brief, that the climatic conditions and their consequence as change in moisture and ventilation, are not included.

While the data of this paper must be translated to field conditions, they apply directly to such tests of bacterial efficiency as the Remy or the Stevens method.

VI. CONCLUSIONS.

For the comparison of bacterial efficiency in soil, and for the study of the influence of soil upon microörganisms, it is necessary to use equal volumes of soil solution as the basis of comparison.

The amount of oxygen that diffuses into a solution under ordinary laboratory conditions, i. e. in a test tube or flask, is by no means sufficient to allow maximum growth of aerobic bacteria. The experiments with *B. mycoides*, *Bact. aceti* and *Azotobacter* show that the development increases with decreasing thickness of the layer of moisture, the maximum being reached at a thickness of 10—20 μ. Experiments concerning the oxygen requirements and oxygen tolerance of bacteria should be carried on with very thin liquid films, as they are found in a coarse sand with 5 to 10% moisture.

If the moisture film becomes less than 10 μ in thickness, the development of bacteria is retarded, because though the oxygen supply is abundant, the diffusion of food to the cells and the diffusion of metabolic products from the cells is not sufficient to allow the fastest metabolism. In this case, the growth will be slower, but the endpoint of decomposition will be the same if the moisture film is thick enough to permit a complete though slow exchange of food and products through the whole soil solution. The rate of decomposition in such soils depends consequently upon the number of cells and their even distribution. If the film becomes very thin, the diffusion ceases almost completely and the cells may die from starvation.

Aeration and thickness of the moisture film are the two controlling factors in quartz sand cultures. They may be considered as the two main physical factors of the soil. They depend both upon the average grainsize and the moisture content.

Aeration increases with the square of the grainsize, while the moisture film increases in direct proportion to the grainsize. A coarse soil is, therefore, of advantage to aerobic bacteria. Aeration decreases with increasing moisture, and the moisture film increases, consequently moisture is desirable only to a limited degree, namely, until the surface film reaches the optimum thickness.

The grainsize of the cultivated soils is so small that the optimum moisture film is reached only in the waterlogged state. Such soils will never reach the maximum rate of decomposition, because the ideal conditions of maximum aeration and optimum moisture film cannot be fulfilled at the same time. The rate of decomposition is necessarily slow, but the final endpoint of decomposition may be the same as in coarse grained soils.

Anaerobic bacteria are favored by increasing moisture, since it increases the film diameter and decreases aeration. They are also favored by a large grainsize. The grainsize of soils may be so small that even saturation with water does not afford optimum conditions for anaerobic bacteria on account of too slow diffusion.

Absorption plays a minor rôle in the bacterial activity of quartz sand cultures.

FOREWORD.

Technical Bulletin No. 17.

BY GEORGE J. BOUYOUCOS.

For nearly two years Dr. Geo. J. Bouyoucos has been making a study of some of the factors affecting the temperature of soils. A description of some of his work and the conclusions drawn therefrom form the subject matter of this bulletin.

This work has been deemed important for the reason that some of the conclusions usually accepted concerning soil temperature have not been satisfactory—have not seemed to accord with observed facts. Apparently these conclusions have been drawn, in part at least, from analogy, and in part without giving due weight to other physical factors involved. Working with facts rather than from analogy, and giving to various factors their proper values the general problem becomes clearer and the conclusions are in accord with the facts of soil behavior.

JOS. A. JEFFERY,
Soil Physicist.

INTRODUCTION.

Soil temperature is one of the essential limiting factors of plant growth. It affects the three most important functions in the soil: the biological, the chemical, and the physical, and thereby controls to a very large extent, the productive power of a soil.

The biological effects at once become evident when it is considered that all life depends not only for its progress, but also for its existence upon soil temperature. Indeed, the germination of seed, the maximum growth of plants, the multiplication and functions of the lower organisms, the taking up of food by plants through osmotic processes, etc., depend to a very large extent, upon soil temperature. Moreover, all these biological processes attain their maximum end not at the minimum, nor yet at the maximum, but at the optimum temperature, which optimum temperature is different for the various kinds of life.

To perceive the chemical role that temperature plays in the soil it will suffice merely to mention that it is a great accelerator of all chemical reactions: it influences the solvent action of water; it influences the velocity of the reaction; it increases the osmotic pressure of the solution; it favors the formation of nitrates; it hastens the weathering of mineral material and the decomposition of organic matter.

From the physical standpoint temperature affects many processes in the soil: it causes a movement of the soil moisture and of the salts due to the change in their surface tension and viscosity; it produces a movement of air on account of the change in pressure. A change in temperature also causes a disintegration of the rocks or soil material due to expansion and contraction.

These biological, chemical, and physical functions of soil temperature emphasize the great importance of the subject and the need for a thorough and extensive knowledge concerning it. Unfortunately our present knowledge of it is very limited. The reasons for this may be divided into two general groups: (1) We do not yet know absolutely the nature of heat and hence of the temperature; and (2) our present methods for measuring soil temperature are very unsatisfactory.

That our knowledge of the nature of heat is yet uncertain will be at once evident if the two views concerning it are considered. The static view considers heat as being a substance and designates it as caloric. The dynamic view, on the other hand, considers heat as a mode of motion; or as a measure of the internal energy of the molecules of the body. All bodies, it maintains, consist of molecules in a state of vibration and the energy of the motion of these molecules determines the temperature of the body; that a difference of temperature between two bodies merely means that a diffference exists in the energy of their molecules; and that this difference may be equalized with the lapse of time by radiation, conduction, and convection until equilibrium results. This dynamic theory of heat established by the experiments of Rumford, Davy, and Joule, has been the accepted view of modern physics, while the static theory has been entirely abandoned. Very recently, however, Callender suggests the idea that this old, discarded caloric theory may be right after all. He maintains that what we call heat and measure as heat, is merely the energy of heat, the heat itself may well be a substance that carries energy as a stream of water carries the energy that turns the mill-wheel.

These different views concerning the nature of heat go to show that after all we are not absolutely sure what heat is, of the laws govern- it, etc., even tho modern physics considered it one of its triumphs that it had demonstrated beyond doubt the nature of heat from the dynamic standpoint.

Undoubtedly by far the greater part of our limited knowledge of soil temperature is due to our unsuitable and unsatisfactory methods or instruments employed for its measurement or study. Until very recently, in fact in all the soil temperature studies that are on record, the mercury thermometers have been used almost exclusively as a means for the measurement of temperature. These instruments, altho in use in almost all scientific temperature investigations, are far from being very satisfactory for the measurement of soil temperature. One of their serious defects is the unequal length of their mercury bulbs, which gives rise to the difficulty of measuring accurately the temperature of the same depth of different soils. In the second place, if the stems are of the same length and the bulbs are placed at different depths, there will be unequal mercury columns exposed to the atmosphere, and thus, on account of the marked difference of temperature in air and soil, there will undoubtedly be an error introduced in the data.

Both these obstacles, however, could be eliminated or obviated to a very large extent by having thermometers made to order with the same length of bulbs and with the proper length of stems. But there are still other disadvantages connected with such instruments such as (1) their fragibility and consequently their unsuitability for long duration or permanent experiments; (2) their inconvenience for reading and consequently the errors that may arise due to parallax; and (3) the adhering of the mercury column to the stem thus giving low or high readings.

Perhaps on account of these difficulties, and also because of the many other complex obstacles involved, the general subject of soil temperature has heretofore received comparatively little investigation. In fact, there is on record no extensive, thoro, and systematic investigation on the subject. Considerable work has been done on certain individual phases of the problem. The first and best scientific study of the subject has been done in Germany by Wollny and his associates. In no other country has the subject received much attention. In America the only important studies are the few practical observations made by King, and the recent work of Patten on heat transference in soils.

While the greater part of the past work is good so far as it goes, there is considerable which is rather inferior, the results of which have led to many erroneous and faulty conclusions. Many of these unsound conclusions have been deducted from short duration experiments; from only one phase of the subject; and from results which were obtained under too artificial conditions. The subject of soil temperature is a most complex problem, and in order to arrive at proper, definite and valid conclusions, it must be investigated from all standpoints, and as far as possible, under both natural and controlled conditions. That the subject demands a broad study for arriving at definite and sound conclusions, is evidenced by the great number of factors which affect or influence it. These factors may be divided into two general groups, intrinsic and external. The intrinsic factors are those contained in the soil, such as specific heat, specific gravity, heat conductivity, radiation, absorption, moisture content, organic matter content, concentration of solution, evaporation, nature of surface, topographic position, etc. The external factors consist of the meteorological elements, chief of which are the air temperature, sunshine, barometric pressure, wind velocity, dew point, humidity, precipitation, etc. Each one of these general groups may be subdivided into two parts, one part tending to impart heat to the soil and thereby raise its temperature, and the other part tending to take away heat from the soil and thereby lower its temperature. These opposing factors are in operation all the time, but some predominate over the others at different seasons of the year. A temperature record, therefore, taken at any time under field conditions may be considered to be the resultant or summation of the effects or forces of these opposing or contesting factors.

In view of the paramount importance of the subject, of our limited knowledge, and the uncertainty of many conclusions concerning it, it has seemed essential and justifiable to undertake an investigation of the problem. Such an investigation, however, to be of the greatest value should be conducted more thoroughly, extensively, and systematically than it has been heretofore. Accordingly the policy followed

has been the following: First, to investigate individually or in combination, many of the chief soil factors affecting the soil temperature; second to study the effects of these various factors on the temperature of the soil under field conditions; and third, to ascertain the relationship between soil temperature and the different meteorological elements.

By attacking the problem from this broad standpoint, and by using the same kinds of soils for the study of many of the soil factors, it was thought that the work would yield more definite and conclusive knowledge, and it would also enable us to form a better and more definite idea as to the magnitude of these respective temperature factors, also which ones are most predominant and play the greatest role in determining or controlling the warmth of the soil.

In the present bulletin are reported the results of the completed laboratory experiments and the results of only one year of the field experiments. It is hoped that the latter experiments will be conducted through a number of years and that the data will be reported from time to time.

SPECIFIC HEAT OF SOILS.

OBJECT AND METHOD OF EXPERIMENTATION.

Specific heat is defined as the number of calories needed to raise one gram of a substance 1° C. The specific heat of soils has received attention from various investigators at different times, notably from Pfaundler,[1] von Schumacher,[2] v. Liebenberg,[3] Lang,[4] Ulrich,[5] and Patten.[6] The results obtained by these investigators for the chief soil types are given in the following table:

TABLE 1.—SPECIFIC HEAT OF SOILS.

	Pfaundler.	Schumacher.	v. Liebenberg.	Lang.	Ulrich.	Patten.
Sand	0.203	.128	.272	.196	.191	.186
Loam	0.208	.205	.188	.214	.208	.204
Clay	....	.190	.161	.233	.224	.155
Peat	0.507	....	.301	.477	.443	....

It is evident that the specific heat of any one type of soil, as found by the different experimenters, is significantly different. The reason for such disagreement is undoubtedly due (1) to the difference in composition of the material, even tho it is designated by the same name; (2) to the different methods employed; and (3) to the difference in technic in the manipulation.

Since it was necessary to know the exact specific heat of the particular types of soil which were to be used for the various phases of soil temperature study, and since such knowledge could not be obtained from the above data, it was deemed essential to ascertain it directly.

(1) Ann. d. Physik u. Chemie 5. Reihe, 9 Bd. (1866): 102–135.
(2) Die Physik Des Bodens, Berlin (1864): 245.
(3) Habilitationschrift Halle 1875.
(4) Forsch. a. d. Geb. d. Agrikulturphysik Bd. 1,: 109.
(5) Forsch. a. d. Geb. d. Agrikulturphysik Bd. 17: 1.
(6) Bul. 59, U. S. Dept. of Agri., Bureau of Soils. 1909.

There are a large number of methods employed for specific heat determination of solid materials, but they are all based upon the method of mixtures. While numerous as are these methods, they are all defective; an error enters into all of them due to the loss of heat during the operation.

The method employed in the present study was devised in the course of the investigation and was adopted in preference to a large number of others that were tried. This method consists in wrapping a definite weight of soil in a known weight of filter paper, tying the latter with a very fine thread, then suspending it in a heater at a temperature of about 97° C. After the soil remained in the heater for two or more hours and had attained a constant temperature it was dropped at once into the calorimeter and stirred vigorously until the maximum temperature was indicated on the thermometer. This temperature was usually obtained in about one minute. The filter paper upon coming in contact with the water would immediately break up and allow the soil contained to mix with the water and thus give up its heat more rapidly than if it had been enclosed in a water-tight vessel as has been done by several investigators, which process delays the reaching of the maximum point on account of the poor heat transference of the soil material. Both the free soil and the filter paper upon becoming wet increased the temperature, but this increase was deducted from the final calculation by ascertaining it in a separate experiment wherein was used the same amount of soil, filter paper, and water as in the regular determinations and having them at about the same temperature (25° C.) The temperature increase due to wetting of the various dry soil powders is considerable, as will be shown subsequently, and unless it is taken into consideration in the final calculation of the results the latter will be altogether too high, especially for certain soils. The size of particles also influences the heat generation due to wetting, consequently in all the different kinds of soils except the gravel, whose specific heat was determined, the same size of particles was used, i. e., those which could pass thru a 40 sieve mesh.

In the determination of the specific heat of the peat it was found that this material would not settle to the bottom of the calorimeter and consequently considerable heat would be lost before the cover of the calorimeter was put on and the stirring process begun. To overcome this difficulty and thereby eliminate the error, a piece of copper was placed with the soil which would cause the soil to immediately fall to the bottom of the calorimeter. The specific heat or water equivalent of this copper piece being known would be deducted from the final calculation of the results. In all these specific heat determinations the temperature was taken by a Beckmann thermometer, and the specific heat apparatus employed was of McCall's type.

SPECIFIC HEAT OF SOILS BY EQUAL WEIGHTS.

The following table represents the specific heat of the different types of soil as determined by the above method, and the different individual data necessary for the calculation of the same. The mechanical analysis of these different types of soil is shown on table 18a.

This table shows that the specific heat of the different types of soil varies very little, that of the quartz sand is the lowest, followed in order

by gravel, clay, loam and peat. The specific heat of the latter soil as determined in this investigation, is very interesting because it is just about half as great as that given to it by some other investigators.

In the above table is also shown the amount of heat generated by the different soils when wetted. It will be seen that this quantity of heat is considerable and becomes greater as the organic matter of the soil increases. In this respect it follows the same law as the specific heat.

The slight difference in the specific heat of the different soils, as shown above, points to the important conclusion that this property plays an insignificant part in the heat relationships of these soils.

TABLE 2.—SPECIFIC HEAT OF SOILS BY EQUAL WEIGHTS.

Name of soil.	Number of trials.	Grams of soil.	Grams of water.	Temperature of water in C.°	Temperature of soil in C.°	Final temperature in C°.	Water equivalent of calorimeter.	Calorimetric system.	Heat due to wetting soil and paper C.°	Specific heat.	Ave. Specific heat.
Sand	1	20	180	19.65	96.70	21.35	11	191	.170	.1934	......
	2	20	180	20.90	95.80	22.55	11	191	.170	.1925	**.1929**
Gravel	1	20	180	19.30	95.10	21.10	11	191	.232	.2017	......
	2	20	180	22.15	96.10	23.95	11	191	.232	.2065	......
	3	20	180	18.55	95.40	20.40	11	191	.232	.2053	**.2045**
Clay	1	20	180	18.30	96.50	20.45	11	191	.526	.2025	......
	2	20	180	19.95	96.40	22.10	11	191	.526	.2072	......
	3	20	180	18.40	96.90	20.60	11	191	.526	.2081	**.2059**
Loam	1	20	180	20.52	96.30	23.05	11	191	.826	.2197	......
	2	20	180	20.05	96.20	22.55	11	191	.826	.2146	......
	3	20	180	21.89	97.10	24.35	11	191	.826	.2120	**.2154**
Peat	1	20	180	21.92	95.40	27.85	11	191	4.04	.2521	......
	2	20	180	20.70	95.00	26.70	11	191	4.04	.2521	......
	3	20	180	21.95	95.90	27.90	11	191	4.01	.2534	**.2525**

SPECIFIC HEAT OF SOILS BY EQUAL VOLUMES.

The next question that arises is what is the specific heat of these same soils when considered from the standpoint of equal volumes. Practically speaking it is the specific heat by equal volume that is important from the agricultural standpoint and not the specific heat by equal weight. In the field it is the depth or volume and not the weight that is heated that is important to the plant.

The specific heat of a soil by equal volume can be obtained by multiplying its specific gravity by its specific heat by weight. The results obtained by this process are shown in the following table:

TABLE 3.—SPECIFIC HEAT OF SOILS BY EQUAL VOLUMES.

Name of soil.	Specific gravity.	Specific heat, equal weight.	Specific heat, equal volume.
Sand	2.664	.1929	.5093
Gravel	2.707	.2045	.5535
Clay	2.762	.2059	.5686
Loam	2.558	.2154	.5507
Peat	1.755	.2525	.4397

It will be seen that the difference in the heat capacity considered from the equal volume standpoint is also small in magnitude between the different soils, but that the order is very different from that of the specific heat by equal weights. In the latter case peat has the highest specific heat and is followed in order by loam, clay, gravel, and finally by sand; while in the case of equal volumes peat has the lowest specific heat with sand, loam, gravel, and clay coming next in respective order.

INFLUENCE OF MOISTURE ON SPECIFIC HEAT OF SOILS.

In field conditions the specific heat of soils by equal volume is also unimportant because the different soils in their natural condition possess different amounts of water on account of their different water holding capacity, and water as will be shown, is one of the predominant controlling agents of soil temperature. With the exception of hydrogen gas, water possesses the highest heat capacity of any other substance. In comparison with that of the dry soils, it is five times greater. This is very significant because it means that it requires five times as much heat to raise the temperature of a unit quantity of water to one degree as is necessary for a unit weight of soil. The different types of soil possessing markedly different water contents, will have entirely different specific heats than those shown above.

To correctly value the tremendous influence that soil moisture has upon soil temperature, this moisture must be determined by volume. Such determination, then, gives a true comparison of the amount of water the different soils may hold under natural condition, which condition from the agricultural or practical standpoint is the most important and satisfactory.

TABLE 4.—EFFECT OF MOISTURE ON THE SOIL TEMPERATURE.

Name of soil.	Wt. of a cu. ft. lbs.	Percent moisture.	Specific heat of soils.	Rise of temp. of dry soils by 100 heat units.	Rise of temp. of moist soils by 100 heat units.
April 3, 1912:					
Gravel	109.2	10.45	.2045	.009854°C	.006520°C
Sand	102.7	16.96	.1915	.011170	.005876
Loam	72.93	40.7	.2154	.014010	.004848
Clay	76.35	29.16	.2059	.013990	.005790
Peat	36.76	256.5	.2525	.023740	.002127
November 4, 1912					
Gravel	109.2	6.91	.2045	.009854	.007365
Sand	102.7	3.78	.1950	.011170	.009208
Loam	72.93	38.12	.2154	.014010	.005056
Clay	76.35	26.81	.2059	.013990	.006079
Peat	36.76	135.5	.2525	.023740	.003725

The moisture content by volume of all the types of soil in which the specific heat has already been considered, has been determined in the following manner: The weight of a cubic foot of each soil was determined in the regular way. Their moisture content was found under the same field conditions many times during the year: in the early spring before they began to thaw, in the middle of the summer, in the late fall when they began to freeze, after a long drought, and immediately after a heavy rain. The percentage of the moisture content found under this variety of conditions multiplied by the weight of a cubic foot of soil gives the amount of water contained in that volume of soil. Knowing the specific heat of water, the influence that the moisture content exerts on soil temperature can readily be calculated. The table below represents the number of degrees Centigrade that 100 heat units will raise or lower the temperature of a cubic foot of the different types of soil.

A careful examination of the table reveals many striking and significant facts. It shows (1) that on account of the great difference in the weight of a cubic foot the influence of the specific heat of equal weight is offset so that the peat which possesses the greatest heat capacity but the lowest weight has its temperature raised about twice as much as that of the sand and gravel which have the lowest specific heat but the greatest weight; (2) the differences in the moisture content are so great in the different types of soil that the influence of the weight of the soil on the temperature is again offset or overshadowed so that the peat which in the dry condition is about twice as warm as the sand or gravel, is now from two to three times colder than the latter soils. This latter fact was actually obtained also in field conditions. The peat for instance, remained frozen in the spring about 10 days longer and in the fall it usually froze after the other soils had frozen. All these facts lead to the important conclusion that while the specific heat as well as the weight play some important part on the ultimate soil temperature, and especially on its ascent and descent, their influences are minimized and indeed overshadowed by the tremendous influence of water with its great heat capacity. Hence it cannot be determined with certainty what the rising or lowering of temperature will be of any particular group of soils merely from the specific heat and weight of a cubic foot, unless the water content also is known.

HEAT CONDUCTIVITY OF SOILS.

OBJECT AND METHOD OF EXPERIMENTATION.

Heat conductivity is defined as the quantity of heat in calories which passes across a cube of unit edge (1 cm), in unit time (1 second), under a uniform temperature gradient of one degree centigrade per centimeter.

Heat conductivity is one of the three modes of heat propagation, the other two are radiation and convection. These three modes of heat

transmission are independent of and essentially different from each other. In the process of conduction the heat is transferred from one body to another, or from one part of the body to another part by contact, or by means of the molecules; while in radiation the heat is propagated as a free-wave motion in the ether without permanently affecting the intervening space between the radiating body and the body receiving the radiant energy. The process of convection, on the other hand, takes place chiefly in liquids and gases, where heat is conveyed or transmitted by the interchange of the unequally heated currents of these liquids or gases.

Heat transference in soils has already received considerable attention from investigators. Especially important is the work on the subject of [7]Haberland, v. [8]Littrow, [9]Pott, [10]Wagner and [11]Patten. The method of study of all these investigators consisted in determining the heat conductivity of powders of soils of different sized particles in dry, moist, and wet condition, and with different degrees of compactness. The materials were placed in a well-insulated vessel, one side of which consisted of some metal which was brought in contact with a constant source of heat. The results obtained by Haberland, v. Littrow, Pott and Wagner are only relative or qualitative, while those of Patten are quantitative.

While the results of all these investigations are valuable and interesting, they have only a theoretical and suggestive value, because they were all obtained under artificial conditions. It is a well-known fact that it is practically impossible to imitate in the laboratory the absolute condition which the soil possesses in the field. The heat conductivity is noticeably influenced by many factors, especially by texture, structure, and moisture content. When one of these factors is changed the others also are changed. Under field conditions, the soil, from long standing, has given these factors an opportunity to come to equilibrium and, therefore, it will possess a certain rate of heat transmission at any given time. In the laboratory, however, these factors cannot be brought into equilibrium, and hence the heat conductivity measurements under this condition have mostly a suggestive and theoretical value, however, qualitative or quantitative they may be.

In order that data on the heat transmission in soils may be of practical value, they must be obtained under natural field conditions. There are many difficulties that arise or are involved in such operations which tend to minimize the importance of the results. In the first place, the different soils possess different shades of colors and would tend to absorb heat unequally and, therefore, would be heated unequally. In the second place, the different soils contain different amounts of moisture and different powers of capillary rise of water, hence there will be unequal evaporation of water on the surface, and consequently a different rate of heating.

(7) Wissenschaftl. praktische Untersuchungen auf dem Gebiete des Pflanzenbaues. Wein 1875.
(8) Sitzungsber. d. k. Akademie d. Wissenschaften 2, Abteil, Wien 1875. Januarheft.
(9) Landw. Versuchs-Stationen Bd. XX: 273 u. f.
(10) Forsch. a. d. Geb. d. Agrikulturphysik Bd. 6:1 u. f.
(11) Bulletin 59, Bureau of Soils, U. S. Department of Agriculture.

HEAT CONDUCTIVITY OF NATURAL SOILS UNDER LABORATORY CONDITIONS.

The next best way to study the heat conductivity which would yield data of practical as well as of theoretical value, would be to cut cores of soils at different seasons of the year, depending upon the meteorological elements which would bring the soils under the different conditions of moisture, texture and structure, and thus measure the heat conductivity of these cores of the different kinds of soils under controlled laboratory conditions. In the present investigation, that is just what was attempted. The method of operation was as follows: Four plates of iron 8 inches long, 7 inches wide, and 1/8 inch thick, with their front and opposite edges sharpened, were pressed or bored into the different types of soil—which types were placed one year before in adjacent wooden boxes 3 x 3 x 3 ft., without top or bottom, as will be explained later—so as to form a square. The soil around the outside of the plates was then removed to its full depth. The plates came out and left the core of the soil standing. A wooden box 8 inches deep, 6 3/4 inches wide, and 1 inch thick, was placed over this core until the top soil was even with the upper side of the box. Next a copper plate was fitted on this side of the box which came in intimate contact with the top of the soil. The bottom of the core was next severed from the ground with a sharp knife, then smoothed and kept in place by a wooden cover. This whole operation, i. e., driving the plates into the ground, placing the box over the core, severing the core from the ground, was done with the greatest possible care so that the structure of the soil core may not be disturbed. Precautions were also taken to secure the core 6 3/4 inches in diameter so that any slight friction on the sides would not affect its structure.

The box which contained the core of soil consisted, as already said, of four wooden sides, one wooden bottom, and one copper top. Before it was placed over the soil, it was boiled in paraffin. Along the center of the lengthwise side, 7 holes were bored one inch apart to admit thermometers.

Four cores of soil were taken, one from sand, loamy, clay, and peat respectively. No core was taken of the gravelly soil since its texture would not permit the plates being driven into it without materially disturbing its structure.

Mention has been made that the top of the core of each soil was smooth and came in contact with the copper plate. To be more certain of this a layer of moist quartz sand was placed over each core before covering it finally with the copper plate. There could now be no doubt of an absolutely perfect contact. Each box was then made air tight by paraffin so that there would be no evaporation. The soils were allowed to remain in the room for several hours to attain the same temperature, before the study of their heat transmission was commenced.

The copper plate end of the box was placed up against the copper side of a tank the water in which was kept at the constant temperature of 33.5° C by means of an electrical arrangement shown in the diagram I. A is a tank filled with water, C is a 32 candle power electric light

by means of which the water is heated. The bulb is connected to the circuit breaker or magnet D which in turn is attached to the thermostat E. F is a stirring fan run by the motor G. H is a stand upon which the soil box rests. This stand is brought as close to the tank as possible and fastened to it by means of a wire, while the soil box is pressed firmly against the side of the tank by means of the screw I.

As soon as the box came in intimate contact with the source of heat, records of the rate at which the heat traveled through the soil were begun. The method adopted to measure this rate of heat transmission was to note the time when the soil box was brought to the constant source of heat also the time when the mercury column of each thermometer began to rise. The bulb of the thermometer was always in the center of the core or about 3 inches deep.

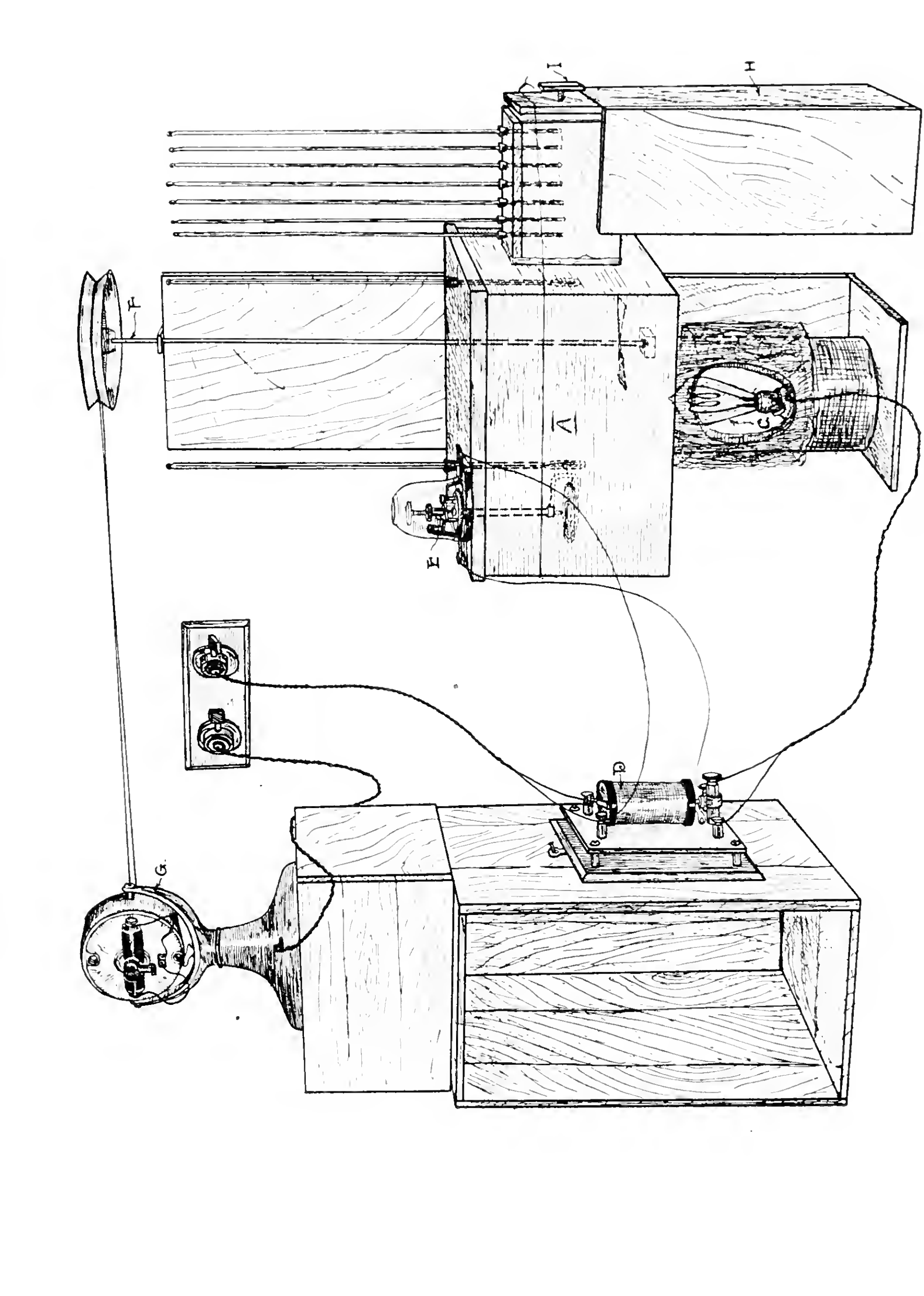

FIG. 1. HEAT CONDUCTIVITY APPARATUS.

It will be evident that the results obtained in this way are qualitative and relative. No attempt was made to determine the heat conductivity in these cores of soils quantitatively because of the many errors involved as shown and enumerated by Patten; also because the quantitative results would not have any more significance either from the theoretical or practical point of view, as the state of the material experimented upon was unstable. The method adopted, however, appears to have been satisfactory and accurate as the readings could be checked within two to four minutes with the exception of the peat in which case the time varied as much as 10 minutes. This discrepancy was undoubtedly due to the fact that the temperature rose so slowly in this soil that it was difficult to note at once the beginning of temperature rise as easily as it was in the other soils.

There was probably no loss of heat from the box as the walls were over one inch thick and well paraffined. The room temperature also remained quite constant throughout the duration of this series of experiments.

The results obtained by the foregoing procedure are shown below. They represent the time that elapsed from the time the soil box came in contact with the source of heat until the time the mercury column of the thermometer at 7 inches from the surface of the soil commenced to rise. The data for the other six thermometers for the first six inches respectively, are left out for the sake of simplicity. The figures for all soils are the averages of four trials. These tests within the same soil did not vary from each other more than three or four minutes except in the peat.

TABLE 5.—HEAT CONDUCTIVITY OF NATURAL SOILS UNDER LABORATORY CONDITIONS.

Name of soil.	Minutes required for thermometer at 7 inches to show rise in temperature.	Percent time required for thermometer at 7 inches to show rise in temperature.
Sand	27	100
Loam	49	181.5
Clay	48	177.8
Peat	124.5	461.2

The results show that the sandy soil conducts heat most rapidly and is followed respectively by clay, loam, and peat. The difference between the sandy soil and peat is very great, the latter allowed the heat to travel thru it only one-third as fast as the former. The differences between the other two soils are very small and in favor of the clay.

HEAT CONDUCTIVITY OF SOILS UNDER FIELD CONDITIONS.

The heat conductivity of the different types of soil under field conditions was determined by taking records every half hour by means of electrical resistance thermometers, which will be explained later, from

seven in the morning till all the thermometers in the different depths or at any particular depth showed a rise in temperature. These different types of soil were contained in adjacent wooden boxes 3 x 3 x 3 feet, without top or bottom, and the soils had lain there for about a year so that they were well compacted by the different climatic agents. They were also covered with a thin layer of a sandy soil so that their insolation and evaporation were more or less equalized. These half-hour records were made at different periods of the season depending upon the condition of the ground, namely, after a long drought, immediately after a heavy rain, and a few days after the rain. By making these observations at different times under this variety of conditions, an idea was obtained as to the relative heat conductivity of these distinct kinds of soils in their natural state under field conditions. The data thus obtained are included below:

TABLE 6.—HEAT CONDUCTIVITY OF SOILS UNDER FIELD CONDITIONS.

Date.	Depth.	Gravel.	Sand.	Loam.	Clay.	Peat.
July 27	6 in.	4 hrs.	4 hrs.	6.30 hrs.	6 hrs.	9 hrs.
	12 in.	7 hrs.	7 hrs.	9.30 hrs.	9.30 hrs.	
August 5	6 in.	4 hrs.	4 hrs.	6 hrs.	5.30 hrs.	8.30 hrs.
	12 in.	7 hrs.	7 hrs.	10 hrs.	9.30 hrs.	
August 26	6 in.	4.30 hrs.	4.30 hrs.	7 hrs.	6 hrs.	9 hrs.
	12 in.	7 hrs.	7 hrs.	10.30 hrs.	10 hrs.	
August 27	6 in.	4 hrs.	4 hrs.	6 hrs.	5.30 hrs.	9 hrs.
	12 in.	6 hrs.	6 hrs.	10.30 hrs.	10.30 hrs.	
September 23	6 in.	4 hrs.	4 hrs.	6.30 hrs.	6 hrs.	9.30 hrs.
	12 in.	5.30 hrs.	5.30 hrs.	9 hrs.	9 hrs.	

The figures in each case indicate the number of hours required for the heat to reach the two different depths from the time the air temperature began to rise. The commencement of the ascent of the air temperature was recorded by means of an air thermograph, which commencement usually took place from about four to six o'clock in the morning. The data show very conclusively that for both the 6 and 12 inch depths at every observation, the gravel and sand exhibit the greatest power of heat conductivity, followed respectively by clay, loam and peat; that the gravel and sand transmit the heat equally well, as do the loam and clay, but that the peat is the poorest heat propagator; also that the differences between the gravel and the sand are nil, between these and the loam and clay quite marked, while the difference between peat and any of the other soils is very great. One of the interesting points to be observed is the fact that the order as well as the magnitude of heat transmission in all these soils, is fairly constant, especially for the six inch depth for all the different observations.

Attention should be called to the perfect agreement in the order of heat transmission of these soils as measured under the field conditions and in the laboratory in the natural state. This interesting parallelism receives most important confirmation in the table below which contains the relative heat conductivity of these soils as determined under the field conditions on the same day that the cores of the respective soils were taken. The state of the material was the same and consequently the heat propagation under the two different conditions can be more truly compared.

TABLE 7.—COMPARISON OF HEAT CONDUCTIVITY OF NATURAL SOILS UNDER FIELD AND LABORATORY CONDITIONS.

Name of soil.	Percent of time required for temperature at 7" to rise. Field conditions.	Percent of time required for temperature at 7" to rise. Laboratory conditions.
Sand	100	100
Loam	150	181
Clay	143	177.8
Peat	362	461.2

This table not only shows the close agreement in the order of the heat conductivity of the different types of soil as measured in their natural state under field and laboratory conditions, but also the more important fact that the magnitude in both cases is very much the same, except in peat in which case there is quite a disagreement.

It must be stated here that these different types of soil under field conditions were all covered with a very thin layer of a sandy soil so as to eliminate the factor of color. This layer of soil incidently performed several other functions, such as the prevention of formation of cracks on the top of the clay and loam soils, the tendency for equalizing the rate of evaporation among the different soils, etc. As a result, the heat conduction values obtained both under laboratory and field conditions approach more closely to the true heat conducting power of these soils. If these different soil types were not covered with the thin layer of the sandy soil the clay and loam would crack on the surface and these cracks would increase the rate of air diffusion and thereby decrease the difference in magnitude of conducting power between the sand and gravel and the clay and the loam.

In connection with the observations made on the heat conductivity of the different types of soil under field conditions, might be mentioned the similar studies made on cultivated, uncultivated and sod land. As will be stated later, the original object of this experiment was to ascertain the effect of these wholly different soil managements on the soil temperature. The temperature of these plots was taken by means of thermographs, the bulbs of which were placed at two different depths, 7 inches and 20 inches respectively. The results obtained are summarized below. The figures show the number of hours required for the heat to arrive at the 7" depth, as indicated by the rise of the temperature, from the time the air temperature began to ascend.

TABLE 8. HEAT CONDUCTIVITY OF FIELD SOILS UNDER CULTIVATED, UNCULTIVATED AND SOD CONDITIONS.

Date.	Depth.	Uncultivated.	Cultivated.	Sod.
July 27	7"	4.0 hrs.	5.0 hrs.	5.0 hrs.
August 5	7"	4.0 hrs	5.0 hrs.	5.30 hrs.
August 26	7"	3.30 hrs.	5.0 hrs.	6.0 hrs.
August 27	7"	4 hrs.	5.0 hrs.	5.30 hrs.
September 23	7"	3.30 hrs.	4.30 hrs.	5.0 hrs.

It will be seen in every observation that the uncultivated ground allowed the heat to pass through it fastest and was followed in order by

about one hour later by the cultivated, and by about one and one-half hours later by the sod land. Evidently the uncultivated ground is the best conductor of heat, the sod the poorest, while the cultivated lies intermediate. The greater moisture content in the cultivated and the vegetation on the sod plots undoubtedly affected the rate of heat transmission.

HEAT CONDUCTIVITY OF SOILS IN THE DRY STATE.

Mention has been made that the heat conductivity of the foregoing types of soil was also studied in the air dry condition. The object of this investigation was two-fold: First, it was desired to ascertain the relative heat transmission of these soils in their water free state as compared with the transmission in their moist or wet state; and second, to see what relationship heat conductivity has to heat radiation of soils in the air dry condition.

This study was conducted in the same manner as the foregoing with the exception that the vessel used to hold the material was a wooden cylinder constructed for the purpose, instead of a box as in the former experiments. This cylinder consisted of white pine and was 8 inches long, 4 inches in diameter and with walls 1 inch thick. On one end was a wooden cover 1 inch thick which could be screwed on, and on the other was a very smooth copper plate tightly fastened on. The soil was poured in always from the side with the wooden cover and then compacted. The compacting was done by Bowman's compacting machine with few modifications. This whole apparatus is shown in Fig. 2. A is an arrangement especially made for the cylinder to rest on the copper cover and placed downward. The soil was poured in the top of the cylinder until the latter was full and then the crank was turned 20 times. The cylinder was filled more and the crank was turned again five times. The cylinder was then taken off the packing machine and all the edges were paraffined to make it air tight, and seven thermometers were placed along its axis at a distance of one inch apart and two inches deep. The cylinder was then placed on a stand as in the preceding experiment, and allowed to remain in the room several hours in order that the soil might acquire the room temperature, the latter remaining quite constant from day to day. The copper end of the cylinder was then brought in contact with the copper side of the source of heat. The temperature of the water in the bath was kept at about 33.5° C. as in the foregoing experiment, and the time required for the mercury column of the different thermometers to show a rise was noted. For simplicity as before, only the data for the thermometer 7 inches from the source of heat are represented below.

TABLE 9.—HEAT CONDUCTIVITY OF SOILS IN DRY STATE.

Name of soil.	Minutes required for thermometer at 7″ to show rise in temperature.	Percent time required for thermometer at 7″ to show rise in temperature.
Sand	38	100
Gravel	36.3	94
Loam	49.7	129.1
Clay	44.2	115.8
Peat	55.2	144.8

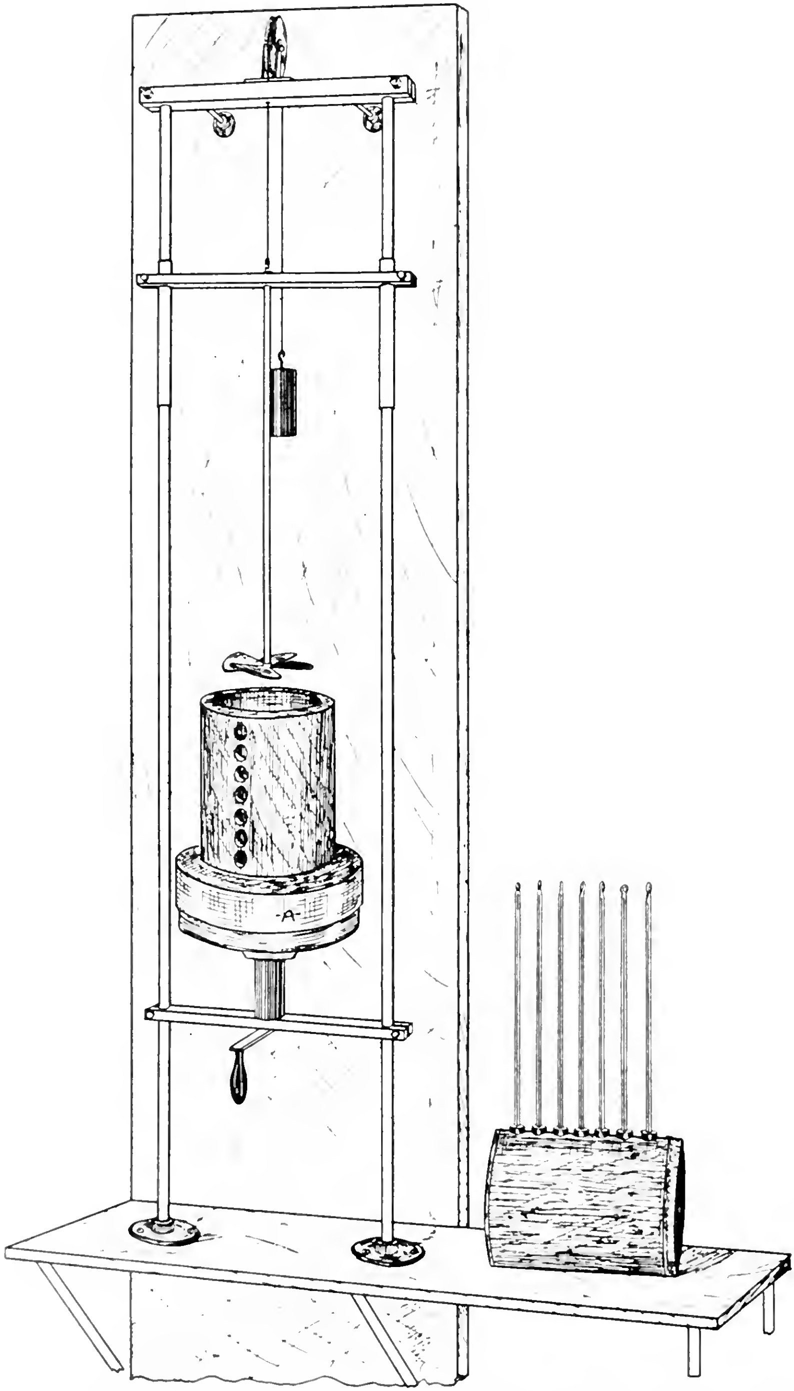

FIG. 2. SOIL PACKING APPARATUS AND CYLINDER CONTAINING THE SOIL.

As in the case of the preceding experiments, this study shows that the gravel in the air dry condition conducts the heat the best and is followed by sand, clay, loam, and peat respectively.

A most interesting fact that was brought out very strikingly in this heat conductivity study of the different soils both in the air dry and moist state, was the difference in time in which the temperature of the column of soil began to rise at the different distances from the source of heat. The table below shows typical examples of this fact. The figures represent the time required for the heat to travel from one inch to another.

TABLE 10.—RATE OF RISE OF TEMPERATURE AT DIFFERENT DISTANCES FROM THE SOURCE OF HEAT.

Name of soil.	1 inch.	2 inch.	3 inch.	4 inch.	5 inch.	6 inch.	7 inch.
	Min.	Min.	Min.	Min.	Min.	Min.	Min.
Dry quartz sand	2	7	6	12	7	3	3
Moist loam	1	5	10	10	9	7	2

It will be seen that the rate of flow of heat decreases until a certain distance is reached and then it increases.

A possible explanation for this phenomenon may be found in the rapid circulation of the soil atmosphere as eddy currents within the minute spaces between the soil grains. These eddy currents are probably set up as hot soil atmosphere on one side of a soil cavity which expands and moves up and is replaced by the colder gases. This circulation of air or convectional currents, undoubtedly greatly decrease the transfer resistance and as a consequence the heat conductivity values obtained do not represent the true and real heat conducting power of the material. To obtain this it is necessary to eliminate entirely these convectional currents. They can be eliminated to a very large extent by heating the soils from the top as, is done under field conditions by sun insolation, but the rate of diffusion would be increased in this case.

As a result of the part that these convectional currents play in heat conductivity, it is believed that the greater thermal transmitting power of the sand over the other soils is partly due to its capacity to allow a greater and more rapid circulation of air.

It will be interesting now to compare the heat conducting power of the different soils in these various conditions, both as to order and magnitude. Attention must be called here, however, to the fact that the magnitude of the results of the air dry soils cannot be compared with those of the moist natural soils because of the fact that the size of the vessels in the two cases was not the same, and consequently the volume of the materials was not the same. Therefore the comparison must be made among the different soils within the same experiment. Bearing this in mind, it will be found then (1) that the order of the thermal conductivity of the different types of soil in the air dry condition is exactly the same as that of the same soils measured in the natural state in the laboratory and under field conditions; and (2) that the differ-

ences in magnitude among the different mineral soils in the air dry state is not very great, as is the case between these and the peat; while in the moist condition, the difference among the various mineral soils is also not highly large but there is a very great difference between them and the peat. This latter anomaly finds its explanation in the large difference in the water content of the two classes of soils. The variations are indeed very great, as shown in the table below which contains the moisture content of the different soils determined at various periods, also at the time when the soil cores were taken.

TABLE 11.—MOISTURE CONTENT OF THE DIFFERENT SOILS UNDER FIELD CONDITION AT DEPTH OF 7 INCHES.

Date.	Gravel.	Sand.	Loam.	Clay.	Peat.
April 3	10.45	11.96	40.70	29.16	256.50
July 27	6.156	3.60	36.64	25.90	148.60
September 9	10.11	5.07	41.49	31.95	159.10
November 1	6.91	3.78	38.12	26.81	135.50
October 20	7.5	4.24	39.52	27.60	234.00

These figures show that the peat usually contains about 25 times as much water as sand or gravel do and about 5 times and 4 times as much water as clay and loam respectively. Now it has been demonstrated that water exerts a tremendous influence upon the thermal conductivity of soil materials both on account of its high specific heat and because of its influence on the structure of the soil. It has been shown also that water is a poorer conductor of heat than the soil material in the ratio of 1:7 when the latter is compacted into a rock; yet water is by far a better thermal transmitter than air. In a well moistened state a soil may transmit heat many times as fast as in the air dry state. In the dry state the soil grains are surrounded by air which acts as an insulation to the passage of heat, consequently the heat transmission is retarded. In the well-moistened condition, however, the air is replaced by the water and the soil grains are enclosed by the water films. These water films perform two functions (1) they replace or expel the air as already stated, and (2) they reduce the pore space and thereby bring the soil particles in more intimate contact or in a more continuous massive condition. It is by producing these effects that water increases so greatly the thermal conductivity of soils so that its own opposing effect, on account of its poorer power of heat transmission, is offset or overshadowed. If water, however, is present in a soil above a certain amount which amount varies with the different soils due to their different water holding capacities, the temperature of this soil will rise more slowly because of the very large heat capacity of water, which is almost five times that of the soil, yet heat will travel faster thru the soil in the more saturated condition than in the moist state. It is on account of the greater water content and hence of the larger specific heat that the peat shows poorer heat transmitting power than the mineral soils in their natural state as compared in their air dry condition. It is an interesting coincidence that the mineral soils and especially the sandy soils have both a better thermal conducting power and a smaller water holding capacity than the peat. These factors

seemingly tend to exaggerate the thermal relations of these series of soils very greatly.

DIRECTION OF SOLAR HEAT IN FIELD SOILS.

It will be interesting to consider at this time the direction in which the solar radiation travels thru the soil and the part that the moisture plays in this progression. At first thought it would seem that the surface heat will travel thru the soil equally in all directions, vertically as well as horizontally. Such, however, may not be the case if the surface varies in color or in other respects, as the following experiments seem to indicate. This point was studied in the following manner: On a very level and smoothed surface ground was spread quartz sand dyed black and very white quartz sand. On the line where the two sands came together, as well as on each side of this line, were placed at various distances, thermometers at the same and at different depths. The temperatures of this ground so treated were read on the thermometers on clear and sunny days. The results obtained are shown herewith:

TABLE 12.—MOVEMENT OF SOLAR HEAT IN SOILS UNDER FIELD CONDITIONS.

Central line sharp, ie., black and white	84.4°F	3″ deep.
1″ from central line towards **black**	**84.4**	3″ deep.
1″ from central line towards white	83.6	3″ deep.
2″ from central line towards **black**	**85.0**	3″ deep.
2″ from central line towards white	83.4	3″ deep.
4″ from central line towards **black**	**85.**	3″ deep.
4″ from central line towards white	82.8	3″ deep.
8″ from central line towards **black**	**86.2**	3″ deep.
8″ from central line towards white	82.4	3″ deep.
8″ from central line towards **black**	**84.0**	4″ deep.
8″ from central line towards white	80.5	4″ deep.
2″ from central line towards **black**	**83.8**	4″ deep.
2″ from central line towards white	82.4	4″ deep.
8″ from central line towards **black**	**82.7**	5″ deep.
8″ from central line towards white	80.0	5″ deep.
1″ from central line towards **black**	**81.5**	5″ deep.
1″ from central line towards white	81.0	5″ deep.

The data show (1) that the temperature of that side of the line having the white sand is much lower than that of the side with the black sand, but that the temperature of the former is much higher near the neutral line than farther away; (2) that a marked difference in temperature may exist within a distance of an inch; and (3) that the temperature of the black sand covered soil is higher at the 4-inch depth than the white sand covered soil at the 3-inch depth when the measurements in both cases are taken at two inches from the central line. At 8 inches from the neutral line the black covered soil at the depth of 5 inches has also a slightly higher temperature than the white covered soil at the depth of only 3 inches.

These results, therefore, seem to indicate very strongly that while the soil temperature tends to travel vertically as well as horizontally, the amount or the facility with which it goes in the former direction is greater than in the latter path. Theoretically that is what should be expected since heat tends to travel at a greater rate in the presence of larger amounts of moisture and since the moisture content of the soil tends to increase with the depth.

The important question to consider next is what part heat conduc-

tivity plays in the control of temperature of the different soils under natural field conditions. This is indeed a very difficult question to answer definitely and satisfactorily for the reason that these soils have different water holding capacities, consequently the great influence that this inequality of water content has upon the travel as well as upon the rise and fall of temperature.

It is commonly believed, however, that heat conductivity has a very important and beneficial influence because the soils with the greater heat conducting power are generally warmer both at the upper surface and at lower depths due to the fact that the heat travels to greater depths during the sun insolation and during the night or cold periods, this heat returns to the surface and thus keeps it warmer. In the case of soils of poor thermal transmitting power only their upper surface will be heated during the sun insolation and during the night this heat will be radiated into space and the soils are left cooler.

Theoretically this argument is sound, but in nature, as shown by the results of the different types of soil, later to be presented, it does not seem to be borne out. It will be found that in the summer, fall, and winter months, the average temperature of all the different types of soil is about the same with a small difference in favor of the loam, clay, and peat respectively. In the spring months, however, the temperature of the sand and gravel began to rise sooner than that of the latter soils. This, however, may be attributed largely to the different amount of heat that is required to warm a cubic foot of the various types of soil to the same degree on account of their different water content. The sameness in temperature of these soils in the fall is also largely due to their different moisture content or specific heats as will be explained.

Everything considered it does not appear that heat conductivity alone plays a very important part in the warming and cooling of the soils in the spring and fall respectively, which seasons from the agricultural or practical standpoint are the most important. The force of this statement will be evident when we come to consider the results of the field experiments. Even the heat conductivity between cultivated and uncultivated soil does not appear to be of such a great practical importance. The difference in temperature that is observed in these differently managed soils is mostly due to the dry mulch at the surface of the cultivated soil.

Where heat conductivity may be of great importance and of practical benefit is in the spring daylight hourly march of soil temperature. If the temperature of a sandy soil at a depth of 6 inches begins to rise two or three hours earlier every day than that of a clay soil, the plants grown in the former soil will have that number of hours of more favorable daylight growth, at which time the carbon assimilation and other activities are at their maximum.

EFFECT OF COLOR ON RADIATION AND THE RADIATING POWER OF SOILS UNDER DIFFERENT CONDITIONS OR TREATMENTS.

OBJECT AND METHOD OF EXPERIMENTATION.

Radiation has already been defined as a process in which heat is propagated as a free-wave motion without permanently affecting the intervening space between the radiating body and the body receiving the radiant energy. The phenomenon is likened to light. Like the latter it is propagated in straight lines; it is reflected and refracted; it travels with great rapidity; and obeys the same laws of propagation.

Our knowledge concerning the rate of radiation or of cooling of substances is unsatisfactory. Newton seems to be the first who performed experiments on the subject. From the data he obtained he enunciated the law to the effect that the quantity of heat lost or gained by a body in a second is proportional to the difference between its temperature and that of the surrounding medium. Dulong and Petit, however, proved that this law is not general but applies only with differences of temperature which do not exceed 15° to 20°. Beyond this, the quantity of heat lost or gained is greater than what is required by this law.

In 1879 Stefan showed, from his own researches and from recalculating his predecessors' data upon the subject, that the rate of radiation of a body is proportional to the fourth power of its absolute temperature.

On account of the great complexity of the phenomenon and of the insurmountable difficulties involved in the technic, the radiating power of only a few substances has been determined. This limited study, however, has conclusively revealed that the different materials have different radiating or emissive capacity. This is also true of the same substance in different conditions and in different temperatures.

In the investigation here presented the main object has been to discover the radiating power of different soils under various conditions or treatments and thereby see, if possible, to what extent radiation affects the temperature of soils. As will be stated later, this subject has remained practically unexplored. Indeed, there has been only one man who has attempted to investigate it.

The different soils experimented with were quartz sand, gravel, loam, clay and peat,—the true representatives of the most common soils.

These soils possess, among other characteristics, distinctive differences in color. It is a common opinion that color has a very marked effect upon the radiation as well as upon the absorption of heat. It is claimed that radiation and absorption are closely related, that the highest absorbers are also the highest radiators and the lowest absorbers are the lowest radiators. A black substance for instance being able to absorb practically all the heat rays on account of its low reflection, low diffusive and high absorptive power, is a high heat absorber and consequently a high heat radiator. The opposite is true of a white substance. A white substance on account of its high reflective, high diffusive and low absorbing power, is a low absorber and, therefore, a low radiator.

It is concluded by some soil physicists, therefore, that a black soil attains a very high temperature during the sun insolation but in the early morning its warmth is about the same if not lower than that of a light colored soil.

A number of physicists have investigated the effect of color on radiation but, as far as the writer is aware, only two have studied it in its application to soil temperature. The first worker was Lang.[12] His method of study consisted of determining the radiation of a white substance first and then mixing this with a colored substance, such as soot, and determining again the radiation of the mixture. He concluded from his results that color affects radiation and absorption equally well.

Several years later [13]Ahr reinvestigated the subject. He employed a slightly different arrangement in the apparatus but used practically the identical material of Lang. He obtained results which were practically the same as his predecessors' but he did not deduct the same conclusions. He thought that the difference in radiation observed in the various colored substances might be due to the composition of the material rather than to the color.

Since this question was still unanswered, and since it was desirable to know definitely whether color does affect radiation in order to arrive at proper conclusions on the radiating power of the different types of soil already mentioned, it was deemed necessary and advisable to investigate the subject. Such investigation, it appeared, should be conducted differently from that of the previous investigators if more definite and conclusive results were to be obtained. One of the greatest difficulties that this study presents, is the fact that there is no single substance of the same composition which contains all the different rays of the spectrum. It seemed, however, that this difficulty might be overcome, to some extent at least, by the following procedure: Instead of using different solid materials of entirely unlike composition to obtain the different colors, it was thought best to use the same kind of solid material colored with the different aniline dyes. The solid substance employed was quartz sand and its radiation as affected by color was measured by an apparatus to be described.

The instruments commonly employed in studying or measuring radiation are the thermopile and bolometer. The bolometer is the more sensitive instrument of the two. On account of various reasons, however, it could not be obtained; consequently at the beginning of the work a high grade thermopile with a very sensitive galvanometer were employed.

The results obtained by this method were unsatisfactory because of the fact that one end of the thermopile was exposed to the room temperature, a slight change in which would change the readings. In order to overcome this difficulty a thermopile was constructed one end of which could be kept in ice water and thus kept under a better controlled temperature. This change or improvement, however, proved of no avail as the electomotive force was so great on account of the large difference in temperature between the two ends that the deflection on the unshunted galvanometer would invariably go beyond the scale.

(12) Forsch. a. d. G. d. Agrik. Phy. I, 1878.
(13) Forsch. a. d. G. d. Agrik. Phy. XVII, 1891.

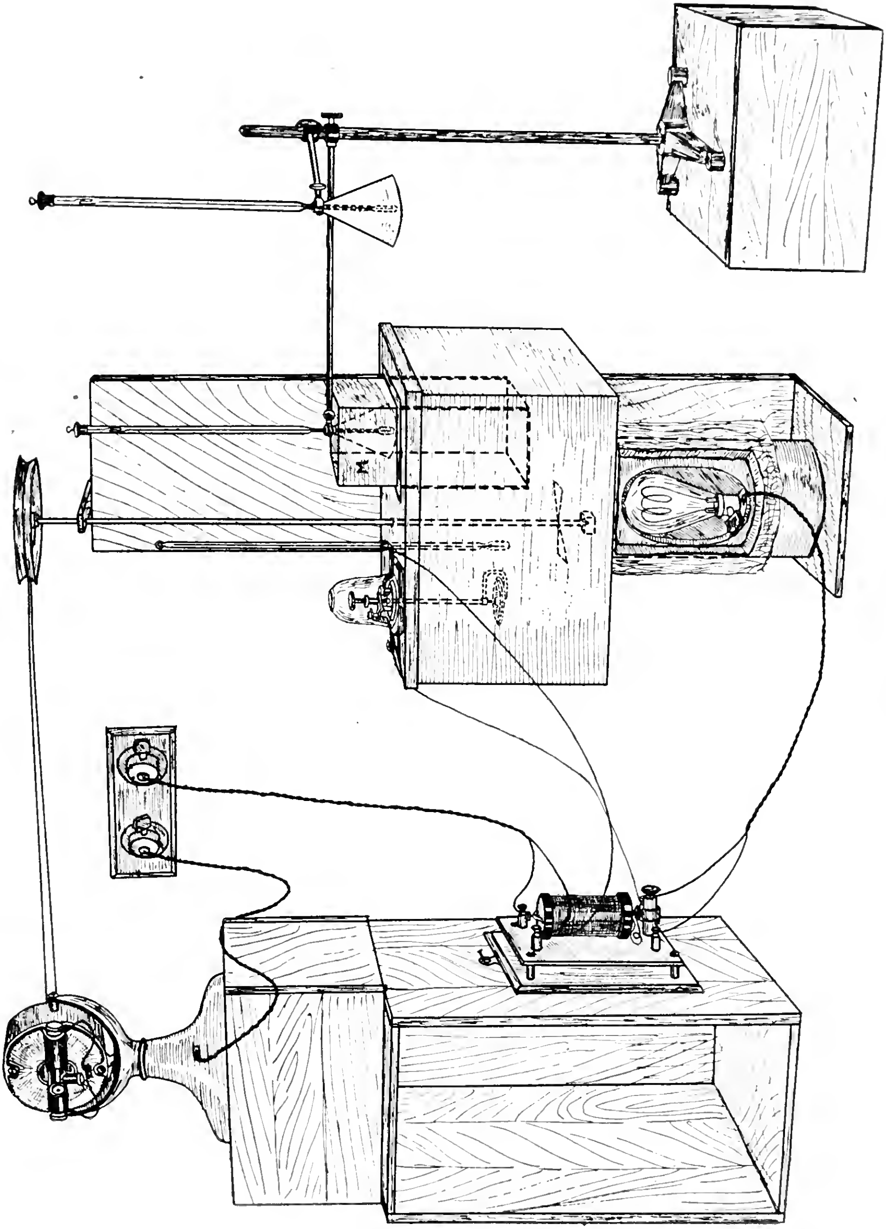

FIG. 3. HEAT RADIATION APPARATUS.

On account of these obstacles, also because of the fact that the accuracy of the thermopile is considerably reduced by the many accidental electrical currents, the thermopile, as a radiometer, was finally abandoned in favor of a Beckmann thermometer. This thermometer gave very satisfactory results.

The complete apparatus employed for the study is shown by diagram 3. With the exception of part M, it is the same as in Fig. I. The part or vessel M is a box in which was placed the sand whose radiation was to be studied. It is made all of copper and it is 6 inches in each dimension. Inside of all four sides were placed asbestos strips 1/8-inch thick and about 10 inches high, or 4 inches higher than the sides, and extending to the bottom—they were intended to prevent any side radiation from the copper vessel or other sources to the thermometer. The box was filled with the sand to a certain height so that the upper surface of the sand would be even with the upper surface of the water in the constant temperature bath, and was left in the latter about 24 hours in order to acquire the constant temperature. The thermometer was placed about one inch from the surface of the sand and its bulb was protected from any side radiations by the cone or hood.

Near the radiation receiving Beckmann thermometer was placed another Beckmann thermometer to indicate the room temperature. Their readings were taken simultaneously and when the reading of the first thermometer is divided by that of the second, a ratio is obtained which is designated as the radiating power of any particular color or soil. Throughout this investigation, then, the relative radiating power of different materials is reduced to this ratio.

This method of measuring the radiating power of substances gave most satisfactory results. If the room temperature was exactly the same the readings of duplicate experiments could be checked to less then 1%. In the measurement or study of the radiating power of any color or soil, therefore, the readings of the two thermometers were taken when the room temperature was about the same as in the previous or standard experiment and the variation did not exceed 0.2° C. To eliminate also any errors that may arise on account of the different reflective powers of the various materials, the readings were taken in every case in dark.

EFFECT OF COLOR ON RADIATION.

There were six different colored sands in which the radiation was measured by the foregoing method. These were white, black, blue, green, red and yellow. The white was the uncolored sand. The results obtained are given herewith:

TABLE 13.—THE RADIATION OF DIFFERENT COLORED SANDS.

Name of colored sands.	Radiation ratio.	Percent radiation.
White	1.060	100.0
Black	1.051	99.15
Blue	1.045	98.10
Green	1.040	98.12
Red	1.050	99.06
Yellow	1.048	98.87

The first column of figures from the left represent the relative radiation ratio. The last column contains the same data reduced to the percentage basis with the white sand as 100% or unit. A glance at these figures reveals at once the fact that the radiating power of the different colored sands is the same, the greatest range being between the white and green sands which is only 1.88% and which is quite within the experimental error.

From these data we are justified in concluding that color has no effect on radiation, at least at this low temperature. It does have on absorption, however, as will be shown below.

EFFECT OF COLOR ON ABSORPTION OF HEAT.

This study was conducted by filling wooden boxes 12 inches square, 2 inches high with bottom and no top, with the various colored sands employed in the preceding investigation, placing them outdoors during *hot* and clear days and recording the temperature at various intervals for 24 or more hours, with mercury thermometers graduated to 0.1° C. There were several experiments conducted but for the sake of brevity only two are given here. The first was conducted on July 27 when the sky was perfectly clear from early morning till about 6 in the afternoon. From this hour on the sky was clouded and about five o'clock the next morning it began to rain. The temperature records were taken every hour during all this time. The second experiment was performed on August 5. This day was also hot and the sky perfectly clear from clouds from morning till evening and even on the succeeding day. The temperature was recorded every hour till the maximum was attained and then at various intervals till late at night, again at 4:30 the next morning before the sun appeared. In the table below, however, only the maximum and minimum readings of both experiments are given. The minimum readings were taken in order to obtain further light on the effect of color on radiation.

TABLE 14.—EFFECT OF COLOR ON THE RISING AND LOWERING OF TEMPERATURE.

Name of colored sand.	July 27–28.		August 5–6.	
	Max.	Min.	Max.	Min.
	2:00 p. m.	4:00 a. m.	1:30 p. m.	4:30 a. m.
Black	40.9 °C	16.7 °C	37.6 °C	12 45°C
Blue	40.0	16.65	36.7	12.4
Red	38.55	16.65	35.9	12.4
Green	37.10	16 60	34 7	12.3
Yellow	35.8	16 60	32.65	12.25
White	34.6	16 44	31.7	12 2

The figures obtained at both times show that the various colors have a most significant different absorptive power for the rays of the sun. The black absorbed the greatest amount and hence attained the highest temperature, followed in order by blue, red, green, yellow and white,

respectively. The difference between the black and white on July 27 was 6.3° C. and on August 5.6° C. The differences between the other colors are not so great, especially between the black and the blue, the yellow and the white, the red and the green.

The minimum figures, on the other hand, show very conclusively at both times that the temperature of all the different colored sands is practically the same, the difference in any extreme not being more than .3° C. and in favor of the sands which had attained the highest temperature. These results are interesting because they lend further confirmation to the conclusions already announced that color has no effect upon radiation. This conclusion, however, may be objected to because if the different colored sands attained different temperatures during the sun insolation because of their different absorptive powers, while during the night they all cooled to the same point, then they radiated differently, and therefore those colors which caused the highest absorption lost the most heat. This is all true but those sands which lost the most heat did not do so on account of the greater radiation of their color, but rather because of the difference between their temperature and that of the air. The law of cooling as announced by Newton states that the rate of cooling of a body is proportional to the difference in temperature between its own and that of the surrounding medium, while the similar law of Stefan states that the rate of cooling or radiation of a body is proportional to the fourth power of its absolute temperature.

Theoretically speaking color should have no effect upon radiation because all colors emit in dark, rays of low refrangibility which are the same while the rays they absorb from the sun are of high refrangibility and are different. The different radiating power observed in the different colored substances is probably due, therefore, to the difference in their composition rather than to their color.

RADIATING POWER OF NATURAL SOILS.

The radiating power of different soils was studied under three different conditions or treatments: (1) in dry and powder state; (2) with moist subsurface and dry surface; and (3) in the natural condition. For convenience these headings will be considered in reverse order.

As has already been stated the radiating power of soils has been studied thus far only by Ahr.[14] He conducted experiments on the radiating capacity of different kinds of soils in the dry, moist, and wet condition. In the dry condition he obtained the following results: quartz 96.5, loam 91.4, calcareous sand 94.1, kaolin 91.5, and humus 89.8%. In the moist and wet condition the values were higher but were the same for all the soils.

In the investigation of heat conductivity, natural cores of soils were employed. These same cores of the different types of soil were also used in the study of radiation with the object of arriving at more definite and practical conclusions as to their radiating power.

The study was conducted by taking off both covers of the box containing the core, pushing the latter very gently with a block of board

(14) Forsch. a. d. G. d. Agrik. Phy. XVII, 1894.

of the same size as the inner side of the box, until it was about 1 inch from the top of the box. That portion of the core which extended beyond the edge of the other end of the box was cut off carefully with a sharp knife. The box containing the core was then placed in a metallic vessel with bottom and no top and made especially to fit this box. That side of the core which rested on the bottom of the vessel, was the subsoil, while that side which was exposed and came to one inch from the top of the box was the surface soil. The latter side was then covered with a very thin sheet of mica in order to prevent evaporation which would have affected the radiation. This mica being diathermous permitted the passage of the radiant energy. The sheet was of the same dimensions as the box so that it rested upon its edges and was about one inch above the surface soil. Its ends were fastened to the edges of the box by means of paraffin, thus making the box air tight. An extension box 5 inches high and 8 inches in diameter was placed on the top of this other box and was also fastened on by paraffin. The ends of the mica came then between the edges of the two boxes. The second or extension box was placed there in order to prevent side radiations on the bulb of the thermometer when it was brought one inch from the surface of the mica to receive the radiation of the soil. The metalic vessel containing the prepared soil box was then placed into the constant temperature bath, the temperature of which always remained at about 33° C. and not varying more than 0.2° C. On the top of this vessel were bended horizontal edges by means of which it was hung from the top or cover of the water tank. In this manner the surface of the soil was always below the surface of the water in the tank. The soil was left in the bath about 24 hours in order to acquire the constant temperature and the radiation readings were taken in the same manner as in the preceding experiment. The radiating power of the cores of all the different soils was studied, then, in this manner and the results obtained are given in the following table:

TABLE 15.—RADIATING POWER OF THE CORES OF THE DIFFERENT SOILS.

Name of soil.	Radiation ratio.	Percent radiation.	Percent moisture.
Sand	1.697	100.00	4.24
Loam	1.694	99.82	39.20
Clay	1.682	99.01	27.6
Peat	1.690	99.59	234.00
Water	1.946	114.70	....

It is at once seen that all the different types of soil in their natural and well-moistened condition possess exactly the same radiating power. Water, however, has a different and much higher radiating capacity. Evidently these results agree with those of Ahr's.

RADIATION OF SOILS WITH MOIST SUBSURFACE AND DRY SURFACE.

During the warm part of the year the soils have a dry surface and a moist subsurface. In order to ascertain what effect this condition

would have upon their radiating capacity the study presented below was undertaken.

It is unfortunate that natural soils could not also be used for this investigation. The study, therefore, had to be conducted with artificial soils in the following manner: The soil was finely ground, moistened, put into the same vessel as that which contained the core of soil, well compacted, covered with the sheet of mica and the extension box put on. The radiation readings were then taken as in the previous case. Then about an inch of the moist soil was removed and replaced by the same kind of soil in a dry and powered form. The box was prepared as usual and the radiation taken again. The difference, if any, between the first and second readings would show whether dry surface with moist subsurface affected the radiation in any way differently from the moist surface and subsurface. The data obtained in this study are given in the table below:

TABLE 16.—RADIATION OF SOILS WITH DRY SURFACE AND MOIST SUBSURFACE.

Name of soil.	Radiation ratio. Moist surface.	Radiation ratio. Dry surface.	Per cent radiation. Moist surface.	Percent radiation. Dry surface.	Percent moisture.
Gravel	1.668	1.512	100	92.11	4.76
Sand	1.668	1.553	100	93.10	5.32
Loam	1.678	1.524	100	90.89	25.85
Clay	1.670	1.530	100	91.06	17.25
Peat	1.502	1.293	100	86.09	81.91
Water	1.946	.....	.....	.....	.....

This table shows very conclusively that all the different soils with a dry surface radiate less than with a moist surface. In other words a dry surface greatly reduces the amount of radiation. It will be seen that all the mineral soils radiated from 7 to 9% and the peat 15% less when they are covered with a dry thin layer of soil than when all the mass is moist. It is interesting to observe that all the mineral soils radiated about the same when moistened through which confirms the results of the preceding experiment—and that their radiation is cut down to about the same amount by their respective dry mulches. The peat, however, shows somewhat a lower radiation. Another noteworthy fact is the insignificant difference in radiation between any of the mineral soils when they are almost saturated and when medium moist. By comparing the first column of the above table with the corresponding one in table 15, it is at once seen that the difference does not amount to more than 1%. In the case of peat, however, the difference runs as high as 11%.

RADIATION OF SOILS IN DRY STATE.

Mention has already been made that the radiating power of the different types of soil was determined also in their air dry state. This study has, of course, more theoretical than practical value but it was undertaken with a three-fold purpose in view: It was desired to ascertain (1) the relative radiating power of these soils in their dry condi-

tion; (2) to see how this compared with their radiating power in their moist state; and (3) to compare their radiating power with their heat transmitting power, in their air dry condition. The investigation was conducted in the same manner as the preceding one with the exception that in the present case all the soils were dry and their particles were of about the same size, i. e., they passed a 40 mesh sieve. This latter precaution was taken because preliminary experiments showed that radiation tends to increase slightly with the increase in size of particles. The results obtained are given in the following table:

TABLE 17.—RADIATION OF THE DIFFERENT SOILS IN THEIR DRY CONDITION.

Name of soil.	Radiation ratio.	Percent radiation.
Sand	1.472	100.00
Gravel	1.375	93.4
Loam	1.369	93.0
Clay	1.391	94.45
Peat	1.194	81.12
Water	1.946	132.2

This table shows that the radiating power of the different soils in the dry condition is different, that the sand shows the highest radiation, followed in order by the gravel, clay, loam and peat, respectively and that the difference between the first and last soil is very marked. This latter fact is highly important because it lends further evidence to the theory that radiation is independent of color. The table also shows that water exhibits the greatest radiating power. This would point to the conclusion that it is the water which increases so markedly the radiating power of moist soils, and which overshadows their radiation possessed in their dry state. This greater radiating capacity of water is contrary to the common belief. The widely held opinion is that water radiates its heat with greater difficulty than any soil material. The truth of the matter is, however, that water loses its heat slowly, not because of its low radiating power but because of its high heat capacity.

It has been stated that the radiating power of these different soils in their dry condition was investigated partly in order to compare it with their heat conducting power. The results show that the two properties run together, a fact contrary to the statements of some physicists.

It now remains to consider the practical significance of the foregoing results. The studies on the specific heat (of dry soils) and heat transference in natural soils led to the conclusion that these two properties play a small part in determining the temperature of the different soils, especially during the important seasons of the year. Radiation plays still a smaller part. This inference is inevitable in the light of what has already been obtained. It has been conclusively shown that all the different types of soil when well moistened possess exactly the same radiating power, and when they have a thin layer of dry mulch this power varies only slightly. This means then that all these soils, under field conditions, cool at the same rate as far as their property of radiation is concerned, the different rate of cooling and warming that is actually observed among these soils is, therefore, due mostly to their different moisture contents and hence to their different specific heats.

TEMPERATURE OF DIFFERENT TYPES OF SOIL.

OBJECT AND METHOD OF EXPERIMENTATION.

This phase of the project had for its primary purpose the investigation of the temperature, under field conditions, of the most common and representative types of soil, namely, gravel, sand, loam, clay and peat. These soils possess so many distinct differences in their physical and chemical properties that it was desired to ascertain whether their temperature relationships would also be different. The mechanical analysis, as determined by the centrifuge method, and the percentage of organic matter, as determined by the loss on ignition method, of these soils, are shown in the following table:

TABLE 18a.—MECHANICAL ANALYSIS AND PERCENTAGE OF ORGANIC MATTER OF THE DIFFERENT TYPES OF SOIL.

Soils.	Stones.	Fine gravel. 2.—1.	Coarse sand 1.—.5.	Medium sand .5—.25.	Fine sand .25—.10.	Very fine sand .10—2.5.	Silt .05—.005.	Clay 0.005.	Per cent organic matter.
Gravel	32	9.70	20.20	51.90	7.10	1.34	5.47	4.29	4.08
Sand		1.42	13.25	67.85	13.10	1.65	1.02	1.71	2.45
Loam		1.66	2.70	13.82	11.66	8.70	47.24	14.22	12.41
Clay				1.78	1.72	3.69	61.13	31.68	7.97
Peat									71.61

Our knowledge concerning the temperature of these different types of soil is very meager. Only two investigators appear to have studied the subject; [15]Wollny and [16]Ebermayer. Wollny made observations of the temperature of sand, clay, and peat for long time. He noticed that sand heats and cools with the greatest rapidity followed by clay and peat and that their average temperature of long period differs but slightly. Ebermayer studied the temperature of sand, clay, loam and peat. From the data he obtained he arrived at practically the same conclusions as Wollny.

The present investigation was conducted in the following manner: A long trench was dug on a smooth and slightly rolling piece of ground a little over 3 feet deep and 3 feet wide. A layer of sandy soil about 6 inches deep was spread over the bottom of this trench so that there would be a uniform bottom. Into this trench, about one foot apart, were placed five wooden boxes 3 x 3 x 3 feet without bottom or top. These boxes were first filled with the above different types of soil about the latter part of September, 1911, were flooded several times in order to compact, and finally were covered with a very thin layer of the same kind of soil in order to eliminate the factor of color. The effect of this factor was investigated in a separate experiment. Their temperature recording was preliminarily begun in the middle of November, but was

(15) Forsch. a. d. G. d. Agrik. Phy. XIX: 305, 1896.
(16) Forsch. a. d. G. d. Agrik. Phy. XIV: 399, 1891.

really commenced on December 1. The temperatures were taken daily except Sundays throughout the year by means of electrical resistance thermometers at three different depths, 6, 12 and 18 inches, at 7 a. m., 12 m., and 6 p. m. The electrical resistance thermometers were obtained from Leeds and Northrup, Philadelphia, Pa., and consisted of the resistance bulb and 35 ft. wire leads. The latter were incased in lead pipes so as to keep them dry and well insulated. The ends of these leads were run into a house especially constructed for the purpose. In this house also was kept on a permanent stand, a balance indicator upon which the temperatures were indicated.

This electrical temperature measuring apparatus gave satisfactory results. If the indicator was in good working order the readings could be relied upon to be accurate to within 0.2° to 0.5° F. The accuracy and sensitiveness was not as high as it was desired, but this lack was somewhat compensated or overcome by taking three readings daily and averaging them. Furthermore, when it is considered that the high and low temperatures recorded during the day do not represent the real maximum and minimum temperatures, then the accuracy of the apparatus is sufficiently high.

As already stated the soil temperature obtained under field conditions is the resultant of many factors. These factors may be divided into two general groups, intrinsic and external. The intrinsic factors comprise specific heat, heat conductivity, thermal absorption and radiation, specific gravity, texture and structure, topographic position, concentration of the soil solution, moisture content, etc. The external includes the meteorological elements, chief of which are air temperature, sunshine, wind velocity, barometric pressure, precipitation, dew point, humidity, etc. The intrinsic factors vary with the different soils and control their temperature for any particular day or season. They are acted upon by the external factors which cause the soil temperature to vary from day to day as they themselves vary. Variations in temperature, therefore, in the different types of soil for any particular period will depend upon their different intrinsic factors, but the variations of all these soils for succeeding days will depend upon the external factors. These meteorological elements influence the soil temperature either directly or indirectly. Pressure, for instance, exerts an indirect effect by either depressing or accelerating evaporation. The amount of evaporation is least when the barometric pressure is high and greatest when it is low.

In connection with the study of the soil temperature of the foregoing soils, these external meteorological factors or elements have also been studied. With the exception of the air temperature which was recorded by an air thermograph located near the soil plots, all the other atmospheric elements were recorded by the proper instruments at the Weather Bureau[17] office which is situated only a very short distance from the experiment.

The following tables show the daily and monthly average, maximum and minimum, also the seasonal and yearly average, maximum and minimum, temperature of the five different types of soil. Each table is accompanied by a diagram to show in a graphic representation its salient

(17) The writer wishes to express his gratitude to Mr. D. E. Seeley for permission to consult and use these weather records.

facts, also the daily march of the meteorological elements and their influence upon the soil temperature.

DAILY AND MONTHLY AVERAGE TEMPERATURE.

TABLE 18.—DAILY AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, DECEMBER, 1911.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	31.8	33.33	36.36	31.83	33.83	37.06	31.96	34.5	37.16	31.96	34.53	36.53	31.93	34.33	37.36
2	31.6	33.23	36.43	31.4	33.6	36.86	31.83	34.5	37.56	31.73	34.73	36.4	32.	34.3	37.63
4	31.6	33.33	36.46	32.	34.13	36.56	32.06	36.96	36.96	32.1	34.63	36.8	31.96	34.33	37.43
5	32.43	34.23	36.33	31.9	33.93	36.8	32.06	36.96	36.93	32.46	34.9	36.73	32.43	34.33	37.3
6	32.26	33.8	36.33	31.96	33.9	36.63	32.4	34.43	36.93	32.33	34.43	36.43	32.06	34.3	37.06
7	31.6	33.33	35.86	31.46	33.43	36.1	31.8	33.96	36.53	32.	33.93	36.	31.8	33.86	36.96
8	32.26	33.93	36.1	32.73	34.1	36.63	32.46	34.76	37.03	32.76	34.73	36.26	32.26	34.5	37.06
9	38.26	37.73	37.53	39.43	38.06	37.73	33.46	35.1	37.3	35.38	36.06	36.96	32.53	34.43	37.
11	41.83	42.06	41.6	41.2	41.7	40.96	40.73	39.96	39.03	41.63	40.6	39.9	32.26	33.9	36.96
12	38.13	40.2	41.2	37.33	39.13	41.06	38.96	40.16	40.4	39.3	40.7	41.	32.5	34.63	37.46
13	36.83	37.83	39.86	35.43	37.46	39.86	36.8	39.1	40.33	36.76	39.23	40.33	32.73	35.2	38.13
14	33.96	35.53	38.23	33.23	35.36	38.16	34.6	37.33	38.76	33.86	36.23	38.6	32.46	34.86	38.1
15	33.33	35.2	37.83	33.16	34.2	37.86	34.1	36.76	38.9	34.	36.53	38.23	32.53	34.8	37.86
16	33.8	35.46	37.76	33.76	35.3	38.06	33.93	36.7	38.96	34.	36.66	38.13	33.23	35.56	38.9
18	33.93	35.46	37.8	33.93	35.7	37.96	33.8	36.06	38.16	34.13	36.16	37.86	33.23	35.86	38.2
19	34.96	36.06	38.	34.66	36.13	38.33	34.5	36.6	38.93	34.8	36.8	38.1	34.1	36.2	38.93
20	33.9	35.76	37.2	33.66	35.13	37.36	33.36	35.83	38.	33.73	36.2	37.83	33.33	35.36	38.26
21	32.96	34.3	36.5	32.6	34.26	36.73	32.5	34.93	37.26	32.6	35.1	36.46	32.2	34.43	37.13
22	32.96	33.56	35.63	33.2	34.06	35.86	32.06	33.96	36.2	32.8	34.46	35.8	31.8	33.63	36.5
23	33.45	34.7	36.4	32.75	34.5	36.45	32.5	34.5	36.1	33.15	34.75	35.85	31.65	33.4	36.35
25	32.5	34.	35.9	32.	33.9	35.8	32.1	34.2	36.4	32.2	34.	35.9	31.9	33.5	36
26	32.23	33.33	35.66	31.66	33.5	36.13	31.56	34.03	35.96	32.13	33.96	35.76	31.76	33.33	36.06
27	31.76	33.56	34.9	32.76	33.73	35.5	31.73	33.73	36.13	32.46	33.53	34.9	32.26	33.53	35.13
28	31.93	32.73	39.16	31.23	33.13	35.93	32.46	34.3	36.73	32.7	34.73	35.4	32.13	34.06	36.1
29	30.5	31.76	34.2	29.96	32.26	35.4	30.93	33.36	35.73	30.93	33.4	35.	31.83	33.4	36.23
30	30.26	31.13	33.43	30.26	31.4	34.33	30.26	32.6	34.63	30.33	32.43	34.2	31.26	32.76	35.36
Monthly average.	**33.50**	**34.83**	**36.87**	**33.29**	**34.84**	**37.16**	**33.27**	**35.41**	**37.40**	**33.55**	**35.52**	**36.98**	**32.32**	**34.35**	**37.13**

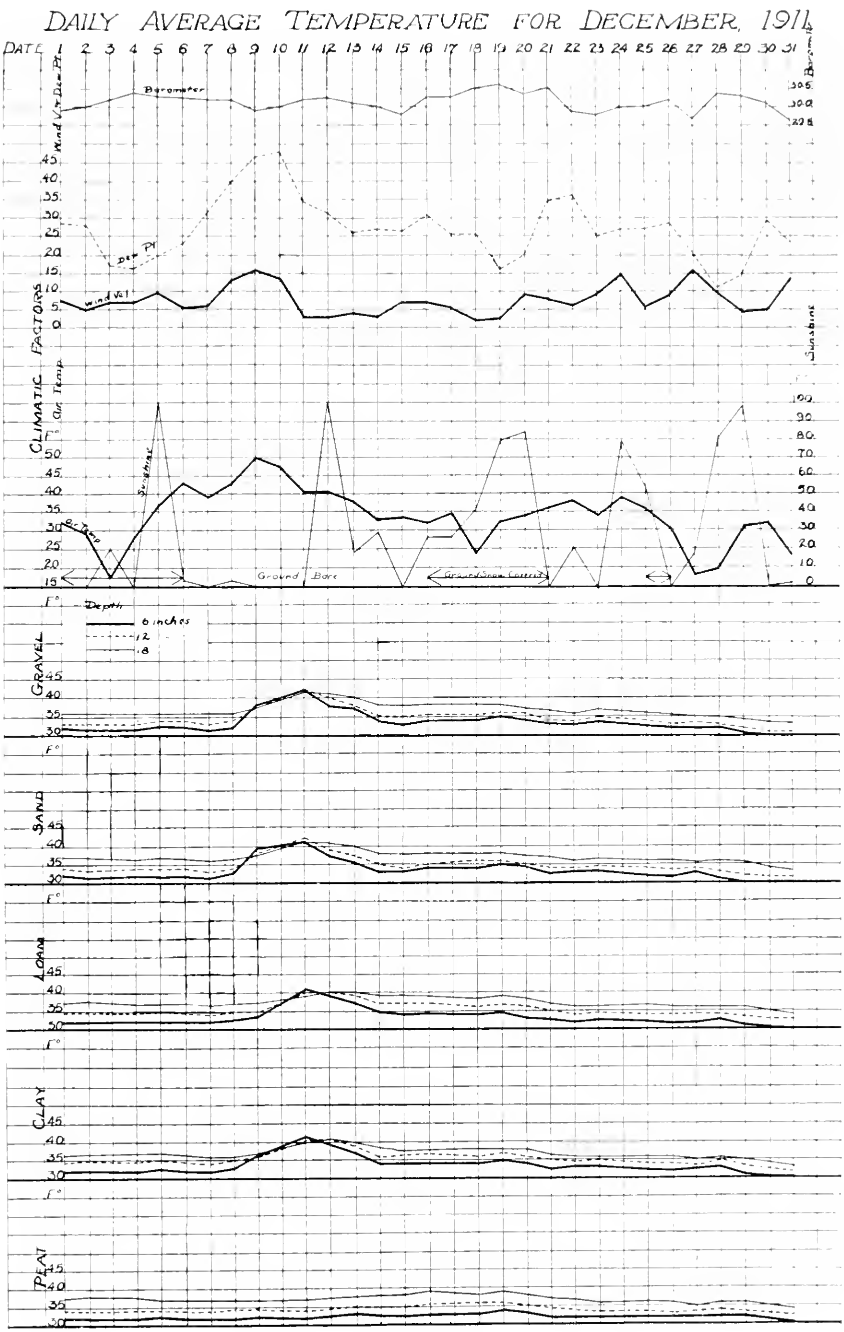
DAILY AVERAGE TEMPERATURE FOR DECEMBER, 1911
DATE 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Barometer
Wind V. & Dew Pt.
Dew Pt
Wind Vel
CLIMATIC FACTORS
Air Temp
Sunshine
Ground Bare
Ground Snow Covered
Depth
6 inches
12
18
GRAVEL
SAND
LOAM
CLAY
PEAT

FIG. 4.

TABLE 19. DAILY AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, JANUARY, 1912.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"
1	29.36	30.53	33.46	29.16	31.4	33.16	29.93	31.96	33.83	30.1	32.36	34.26	31.46	32.36	35.16
2	27.5	30.43	32.86	27	30.26	33.43	28.86	31.2	33.86	29.4	31.26	32.63	29.06	31.1	34.33
3	22.6	26.66	29.9	20.86	27.93	31.46	26.86	31.03	32.96	27.63	30.9	32.73	28.8	31.13	33.96
4	26.06	29.13	33.36	24.16	29.66	34.16	28.86	32.86	35.3	28.63	32.6	34.5	29.83	33.06	35.83
5	20.86	26.26	32.66	18.16	26.86	33.3	25.33	32.16	35.	25.66	31.9	33.93	25.4	32.5	35.23
6	19.96	24.16	31.7	14.73	24.7	32.73	23.16	31.73	34.53	23.53	31.5	33.86	21.23	32.16	35.26
8	20.03	23.26	29.8	16.33	23	31.4	21.86	29.53	33.56	21.7	28.86	32.6	19.63	31.73	34.06
9	24.23	26.26	30.23	20.96	25.6	31.46	24.33	28.8	32.63	23.46	27.8	31.66	21.66	31.	33.83
10	25.36	27.4	30.6	23.13	26.93	31.26	25.06	29.13	32.56	24.6	28.53	31.23	23.16	30.76	33.66
11	25.83	27.83	30.33	23.8	27.66	31.36	26.3	29.06	32.56	24.56	28.03	31.36	23.93	30.2	33.46
12	26.13	27.6	30.13	23.93	27.46	30.6	26.76	29.06	31.23	24.46	27.86	30.76	23.13	28.9	32.86
13	24.5	26.73	29.7	23.23	27.13	30.26	25	28.16	31.23	22.23	27.16	30.46	21.83	27.8	32.2
15	25.46	27.9	30.63	24.7	27.76	30.7	25.5	28.6	31.56	24.3	27.5	30.43	24.23	28.16	32.53
16	25.26	27.56	30.3	23.93	27.7	30.5	25.4	28.76	31.46	24.3	27.26	30.	23.3	28.2	32.33
17	21.76	26.83	29.73	23.9	26.9	30.1	25.26	28.7	31.06	24.66	27.13	30.03	23.4	27.96	32.16
18	28	29.1	30.9	26.56	28.83	31.3	27.03	29.	31.7	26.66	28.23	30.46	26.33	28.7	32.6
19	29.33	29.9	30.96	28.16	29.86	31.36	27.43	29.16	31.7	27.46	28.7	30.43	26.9	28.76	32.73
20	27.3	28.1	30.5	25.5	28.8	30.5	26.36	28.6	30.5	26.63	28.63	29.9	25.63	28.23	31.7
22	27.66	28.13	30.23	26.83	28.8	30.4	26.13	28.8	30.7	27.03	28.73	29.83	25.73	27.96	31.8
23	28.13	29.03	30.56	27.43	29.3	30.66	27.9	28.86	30.83	27.9	27.03	30.1	26.66	28.5	31.93
24	28.83	29.9	31.33	28.2	30.13	31.66	28.26	29.96	31.43	28.53	29.9	30.86	27.33	29.13	32.1
25	28.8	29.8	31.63	27.83	30	31.63	28.06	29.96	31.56	28.36	29.7	31.03	27.06	29.03	32.16
26	28.56	29.53	31.3	27.36	29.93	31.43	28.03	29.93	31.53	28.2	29.96	32.3	27.06	29.16	32.3
27	28.93	29.9	31.2	27.63	30.1	31.6	28.1	29.9	31.36	28.53	29.86	30.76	27.23	29.3	31.96
29	28.2	29.03	30.63	27.13	20.06	30.93	27.53	29.03	30.83	28.03	29.16	30.16	26.73	28.66	31.43
30	28.03	29.03	29.86	26.93	28.26	30.43	27.1	28.5	30.23	27.73	28.63	29.73	26.6	28.1	30.76
31	28.93	29.63	30.53	27.9	29.26	30.96	27.96	29.03	30.86	28.53	29.03	30.03	27.53	28.9	30.9
Monthly average	**26.24**	**28.14**	**30.93**	**24.62**	**28.27**	**31.44**	**26.60**	**29.68**	**32.10**	**26.40**	**29.27**	**31.34**	**25.58**	**29.68**	**32.94**

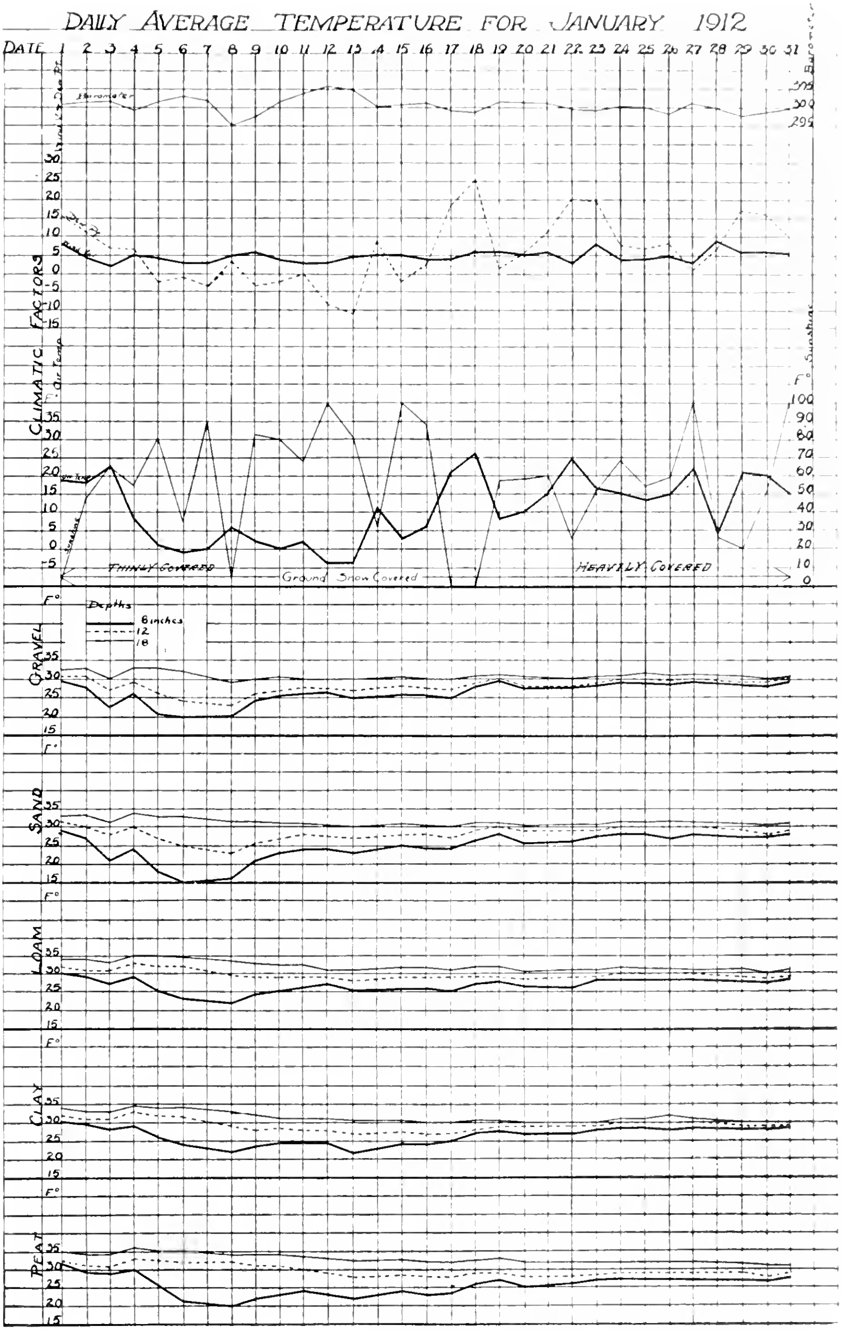
DAILY AVERAGE TEMPERATURE FOR JANUARY 1912
DATE
CLIMATIC FACTORS
Barometer
Dew Pt.
Air Temp.
Sunshine
THINLY COVERED
Ground Snow Covered
HEAVILY COVERED
Depths
6 inches
12
18
GRAVEL
SAND
LOAM
CLAY
PEAT

FIG. 5.

TABLE 20. DAILY AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, FEBRUARY, 1912.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6"	12"	18"	6"	12"	18"	6"	12"	18"	9"	12"	18"	6"	12"	18"
1	28.9	29.8	30.8	27.46	29.43	31.03	28.03	29.	30.86	28.33	29.2	30.3	27.23	28.8	31.13
2	28.86	29.9	31.1	27.53	29.56	31	28.16	29.1	30.93	28.4	29.26	30.26	27.13	28.5	31.23
3	28.7	29.76	30.93	27.3	29.33	30.8	28.23	29.03	30.66	28.56	29.53	30.53	27.26	29.03	31.16
5	28.53	29.86	31.1	27.43	29.8	31.2	28.06	30	30.96	28.3	29.96	30.63	27.26	28.83	31.03
6	28.43	29.73	31.33	27.16	29.9	31.33	28	29.86	31.53	28.63	30.33	31.03	26.96	29.13	31.86
7	28.43	29.93	31.06	27.03	29.8	31.16	28.06	29.6	31.4	28.56	30.03	30.9	27.03	28.96	31.9
8	28.3	29.33	30.53	26.96	29.8	31.1	27.53	29	30.83	27.96	29.56	30.33	26.93	28.9	31.43
9	28.6	29.53	31.03	26.7	29.73	31.53	27.86	29.9	31.2	28.5	29.53	30.5	27.26	29.16	32
10	27.73	28.96	30.93	23.6	28.5	31.13	26.16	29.53	30.86	26.46	29.03	30.33	26.76	28.76	31.16
12	28	29.03	30.93	25.13	28.2	30.7	26.16	29.16	30.9	26.3	28.9	30.16	26.36	28.6	31.56
13	27.66	28.93	30.6	25.23	28.1	30.43	26.66	28.53	30.46	26.03	28.93	29.9	26.73	28.53	31.2
14	28.03	28.93	30.63	25.56	28.53	30.3	26.2	28.4	30.66	26.33	28.43	30	27	28.43	31.4
15	28.8	29.43	30.56	26.83	29.03	30.5	26.96	28.63	30.86	27.	28.7	30.03	27.4	28.6	31.26
16	28.93	29.5	30.3	28.03	29.3	30.3	27.2	28.4	30.2	27.43	28.83	29.43	27.83	28.8	31.06
17	28.63	29.1	30.06	28.06	29.1	30.16	27.33	28.2	29.6	27.3	28.53	29.36	28.23	28.96	30.93
19	29.8	30.1	30.7	30.26	30.43	31.16	29.5	29.53	30.23	28.66	28.66	30.06	29.5	29.7	31.03
20	30.4	30.83	31.4	30.93	31.1	30.33	29.33	29.96	30.83	29.7	29.83	30.76	29.96	30.06	31.13
22	29.3	29.5	29.6	29.4	30.1	29.2	28.7	29.5	29.9	29.8	29.6	30.1	29.7	30.5	30.2
23	29.45	29.95	30.65	30.2	30.35	30.93	28.85	29.55	30.45	28.85	29.8	30.4	28.55	30.05	31.4
24	30.25	30.95	30.8	31.15	30.85	30.8	29.95	30.3	30.65	30	30.1	30.6	29.45	30.2	30.7
26	30.9	31.13	31.1	31.03	31.2	31.43	29.5	30.13	30.9	29.93	30.53	30.73	29.93	29.9	31.06
27	30.46	31.06	31.3	31.4	31.36	31.56	29.73	30.26	31.16	30.16	30.56	30.96	30.4	30.36	31.66
28	30.96	31.2	31.2	31.06	31.46	31.53	29.8	30.16	31	30.16	30.4	30.9	30.3	30.26	31.43
29	31.03	31.23	31.46	31.	31.23	31.53	29.96	30.46	31.2	30.5	30.66	31.26	30.7	30.43	31.4
Monthly average.	29.13	29.90	31.44	28.20	29.84	30.88	28.17	29.43	30.75	28.41	29.52	30.39	28.15	29.31	31.27

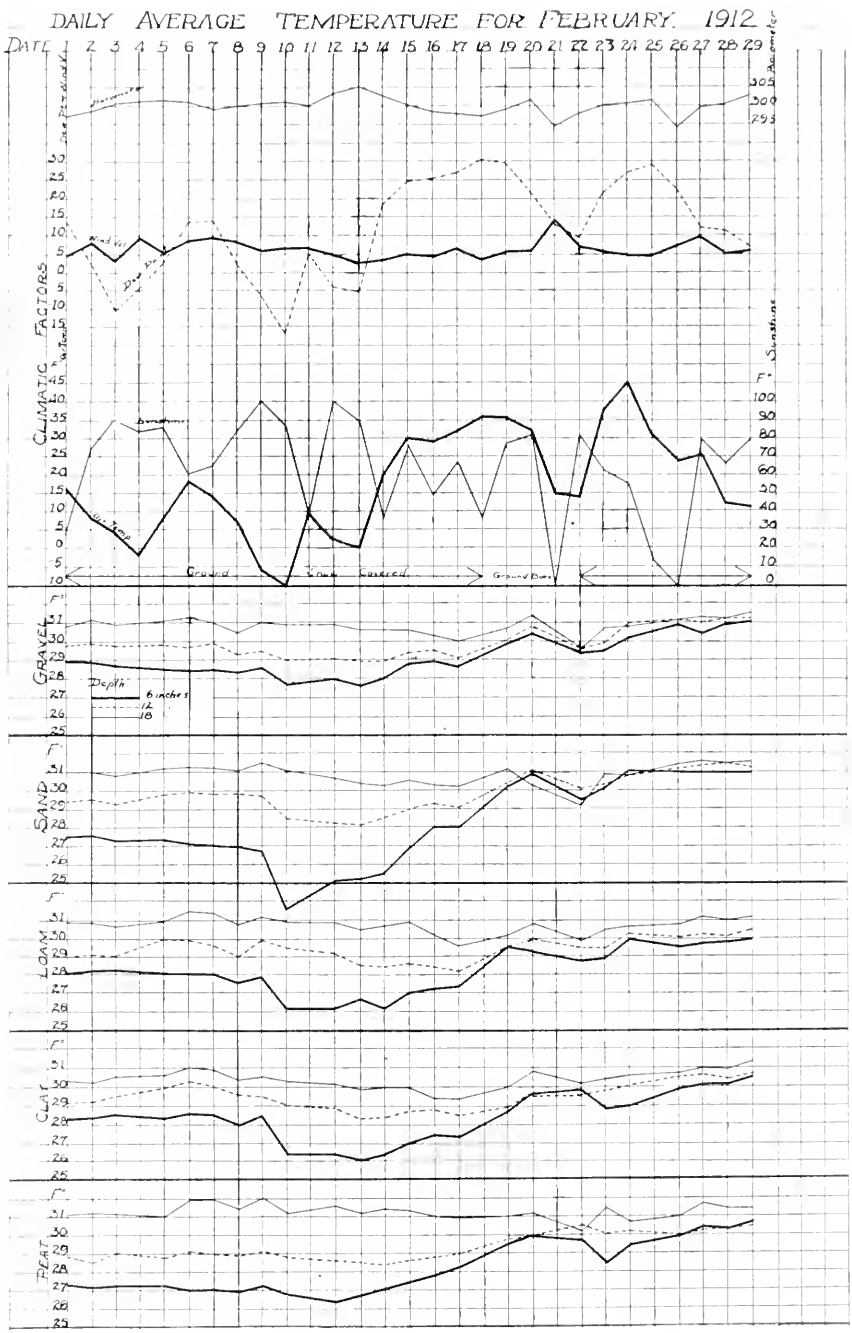
DAILY AVERAGE TEMPERATURE FOR FEBRUARY. 1912
DATE 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Barometer
Wind Vel.
Dew Pt.
CLIMATIC FACTORS
Sunshine
Air Temp.
Ground Snow Covered
Ground Bare
GRAVEL
Depth 6 inches 12 18
SAND
LOAM
CLAY
PEAT

FIG. 6.

TABLE 21. DAILY AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, MARCH, 1912.

Date	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1...	31.	31.2	31.55	31.1	31.25	31.7	29.96	30.45	31.1	30.65	30.53	31.3	30.5	30.65	31.4
2...	30.96	31.23	31.36	31.	31.43	31.86	29.96	30.5	31.3	30.43	30.93	31.46	30.36	30.8	31.73
4...	30.86	31.03	31.46	30.9	31.13	31.86	29.8	30.93	31.4	30.5	31.03	31.56	29.83	30.4	31.6
5...	29.95	30.6	31.35	30.35	31.1	31.9	29.45	30.85	31.2	29.7	30.9	31.15	29.3	30.25	31.35
6...	29.25	30.15	31.15	29.55	31.	31.65	28.75	29.95	30.65	29.1	30.	30.8	28.7	29.65	31.25
7...	29.03	30.06	31.56	29.6	31.	32.03	29.03	30.16	31.3	29.7	30.5	31.16	28.06	29.83	31.3
8...	29.03	29.76	31.	29.4	30.36	31.4	28.63	29.53	30.43	29.06	29.76	30.56	28.56	29.56	31.13
9...	29.86	30.33	31.06	30.03	30.76	31.36	29.16	30.	30.76	29.23	29.93	30.26	28.9	29.26	31.2
11...	30.	30.53	31.53	29.96	31.13	31.76	29.23	30.13	31.03	29.96	30.53	31.2	29.6	29.9	31.43
12...	29.56	31.1	31.03	29.56	30.76	31.3	29.26	30.	30.53	29.66	30.1	30.6	29.3	29.9	30.96
13...	30.16	30.63	31.53	30.2	30.9	31.5	29.6	30.16	30.83	30.	30.3	31.03	29.7	30.13	31.37
14...	29.7	29.9	30.7	29.4	30.23	31.13	29.06	29.73	30.6	29.4	29.8	30.33	28.86	29.46	30.46
15...	30.2	30.4	31.2	30.	30.3	31.2	30.	30.5	31.4	29.9	30.4	31.3	29.8	30.3	31.
16...	29.93	30.3	30.93	29.83	30.3	31.3	29.33	29.86	30.53	30.06	30.33	30.86	29.56	29.86	30.9
18...	30.16	30.5	30.96	30.16	30.6	31.3	29.43	30.1	30.9	29.93	30.16	30.9	29.86	29.96	31.
19...	30.33	30.63	31.03	30.5	30.83	31.46	29.63	30.	30.83	30.03	30.3	30.66	30.03	30.	31.06
21...	28.56	29.13	30.1	29.5	29.8	30.36	28.33	28.93	29.36	28.96	29.33	29.7	28.66	29.33	30.26
22...	28.4	29.26	30.2	29.5	30.3	30.26	28.53	29.4	29.46	29.2	29.83	29.9	29.26	29.8	30.13
23...	29.36	30.1	30.3	29.96	30.26	31.23	29.9	29.9	29.7	30.	30.4	30.33	29.93	29.66	31.2
25...	29.7	30.21	31.36	30.3	31.2	31.5	29.73	30.3	31.13	29.96	30.43	31.1	29.9	29.93	31.4
26...	30.36	31.	31.36	30.7	30.73	31.6	29.46	30.3	30.36	29.86	30.23	30.5	29.86	30.1	31.2
27...	30.2	30.7	30.96	30.2	30.76	31.53	30.06	30.4	31.16	30.6	30.66	31.03	29.96	30.46	31.46
28...	30.4	30.93	30.83	30.5	30.9	31.56	30.	30.53	30.63	30.43	3.50	30.86	29.83	30.6	31.56
29...	30.46	30.26	30.6	30.16	30.33	30.7	29.86	30.16	30.66	30.03	30.83	30.96	30.2	30.1	30.93
30...	30.3	30.76	30.86	30.86	30.8	31.96	30.43	30.33	30.8	30.33	30.93	31.	30.76	30.53	30.93
Monthly average...	**29.91**	**30.43**	**31.04**	**30.13**	**30.72**	**31.42**	**29.46**	**30.13**	**30.72**	**29.87**	**30.35**	**30.83**	**28.36**	**30.02**	**31.13**

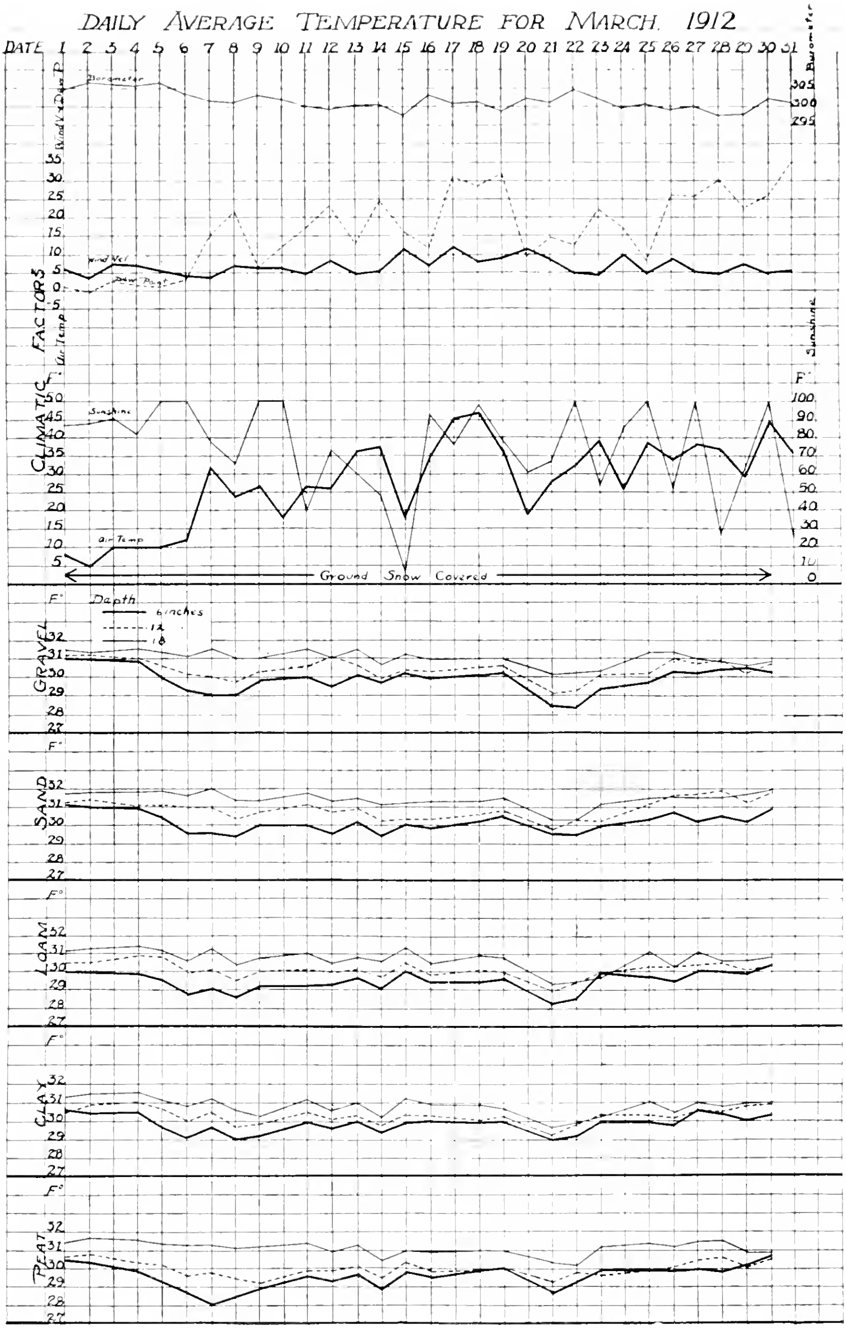
DAILY AVERAGE TEMPERATURE FOR MARCH, 1912
DATE
Barometer
Wind Vel. & Dew P.
Wind Vel.
Dew Point
Air Temp.
Sunshine
CLIMATIC FACTORS
F°
Ground Snow Covered
Depth
6 inches
12
18
GRAVEL
SAND
LOAM
CLAY
PEAT

FIG. 7.

TABLE 22. DAILY AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, APRIL, 1912

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	31.83	31.8	31.56	31.4	31.86	31.8	31.1	31.46	31.76	31.73	31.6	31.7	31.43	31.43	31.76
2	30.93	30.96	30.96	31.06	31.06	31.1	30.53	30.76	30.93	30.93	31	30.86	30.76	30.5	31
3	30.06	30.33	29.93	30.06	30.16	30.06	30.36	30.9	31.1	30.86	31	31.03	30.8	29.96	30.73
4	31.23	30.66	30.56	30.43	30.66	31.06	30.2	30.2	30.53	30.13	30.53	30.56	30.1	29.7	30
5	35.96	32.33	31.23	33.5	30.96	31.4	30.2	30.43	30.93	31.96	30.9	30.9	30.5	30.2	30.16
6	40.5	36.83	31.93	38.8	33.66	31.8	30.96	30.23	30.9	35.86	30.86	30.86	30.4	30	31.06
7	39.93	39.66	37.0	36.83	36.20	34.63	32.46	30.16	30.9	36.16	30.80	30.76	30.10	30.10	30.96
8	36.1	35.6	35	34.8	34.16	33.8	31.73	30.43	30.96	33.23	30.9	30.8	30.7	30.33	31.13
9	40.56	38.63	36.03	40.5	37.63	35.26	34.06	30.33	31	36.8	31.13	30.9	30.6	30.43	31.03
10	42	40.53	37.86	42.26	39.8	37.46	35.2	30.46	30.86	38.13	32.46	31	30.56	30.33	31.06
11	45.16	42.32	39.06	44.9	41.5	38.33	36.93	30.5	30.96	39.83	33.7	30.86	30.73	30.16	31.03
12	46.5	43.13	41.16	45.76	43.43	40	38.86	31.53	30.96	42.96	37.76	34.33	30.6	30.16	30.93
13	45.16	44.1	41.53	44.6	43.13	40.63	38.46	32.93	31.66	43.23	30.86	37.63	30.7	30.13	30.96
15	47	45.43	41.93	46.6	43.9	41.03	44.86	40.36	35.03	45.63	41.5	39.23	32.83	39.93	31.2
16	46.43	45.83	43.53	45.86	44.73	42.86	44	41.73	38.73	46.23	43.73	41.56	33.36	30.3	31.06
17	43.4	43.56	43.03	42.76	42.66	42.3	42.46	42.16	40.36	43.86	43.26	42.02	33.96	30.26	31.3
18	40.76	41.53	42	40.13	40.4	40.66	40.46	41.3	40.36	41.16	41.76	41.33	33.56	30.56	31.56
19	40.8	40.53	40.56	40.4	40.13	39.96	39.63	40	39.9	40.63	39.93	40.1	33.1	30.36	31.66
20	38.96	38.13	39.66	39.66	39.4	39.83	40.93	40	40.33	39.33	40.53	39.3	34.06	30.06	31.8
22	47.36	46.66	44.33	46.76	46.2	44.23	47.36	44.73	41.8	47.7	44.6	43.4	39.13	30.6	31.86
23	42.96	42.73	42.43	43.33	42.33	42.53	42.6	42.96	41.86	42.56	42.63	42.16	36.03	30.46	31.86
24	47.73	45.96	43.36	47.96	45.36	43.1	46.06	43.7	41.76	46.46	43.66	42.36	38.36	30.4	32
25	47.13	46.	44.03	47.2	45.16	43.56	46.6	44.4	42.23	46.53	41.7	43.23	38.86	30.56	32.03
26	50.43	48.66	45.8	50.73	47.8	45.1	49.13	46.5	43.63	49.83	46.2	44.8	41.73	30.8	32.7
27	50.73	49.36	46.46	50.83	48.9	46.56	50.16	47.76	44.56	50.83	47.46	45.7	43.36	30.96	33
29	43.2	43.5	44.23	42.6	43.16	43.9	44.33	45.16	44.7	43.83	44.7	44.53	40.23	31.46	34.06
30	44.3	43.13	42.76	45.03	43.06	42.76	43.16	43.33	43.26	43.66	43.03	43.36	38.66	31.43	34.56
Monthly average	41.81	40.70	39.27	41.46	40.04	38.92	39.16	37.47	36.58	40.20	38.44	37.48	34.04	35.48	31.59

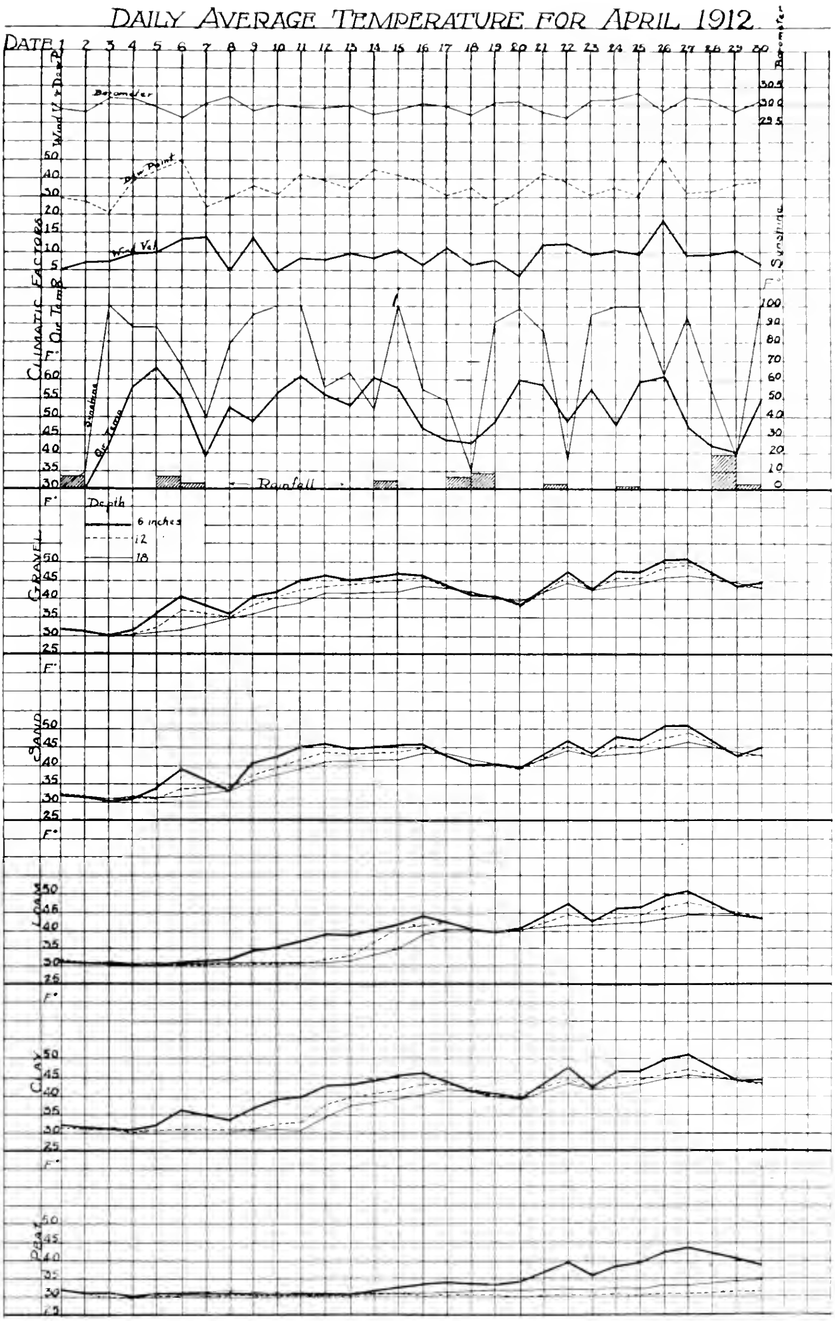
DAILY AVERAGE TEMPERATURE FOR APRIL 1912.
DATE 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Barometer
Dew Point
Wind Vel.
Sunshine
Air Temp.
Rainfall
CLIMATIC FACTORS
Depth
6 inches
12
18
GRAVEL
SAND
LOAM
CLAY
PEAT

FIG. 8.

TABLE 23. DAILY AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOILS, MAY, 1912.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1 ..	45.56	45.53	44.63	45.73	45.53	44.53	45	44.53	43.23	45.4	44.66	43.93	42	32.6	35.63
2	48.93	46.76	44.6	49.33	46.6	44.76	46.63	44.8	43.76	47.73	45.1	44.23	42.93	34.6	36.96
3 .	53.03	50.43	46.86	53.23	49.96	47.8	50.5	46.83	44.6	52.03	47.83	45.66	47.5	38.7	39.66
4 .	55	52.53	48.53	55.13	52.23	48.13	53.33	49.33	46.03	54.46	49.83	47.76	51.2	44.5	42.86
6 .	57.8	54.76	50.6	57.46	54.16	50.46	55.66	52.16	48.56	57.13	52.36	50	55.6	49.7	46.96
7 ...	60.10	57.36	52.7	60.03	56.83	52.16	59.	54.36	49.86	60.13	54.76	51.8	58.86	52.03	48.66
8	57.2	55.96	53.1	56.73	55.03	52.66	57.6	55.16	50.96	57.93	54.96	52.9	59.43	54.1	49.93
9 .	55.03	54.06	52.26	54.86	53.23	51.73	54.83	53.96	51.33	55.66	54.26	52.63	57.76	54.63	51.66
10 ..	57.	54.9	52.13	57.33	54.33	51.76	55.83	53.4	50.8	56.9	53.8	52	57.53	54.4	51.66
11 .	57.36	55.63	52.66	55.83	54.86	52.5	56.66	54.4	50.63	57.06	54.63	52.33	58.9	54.93	51.83
13. .	46.8	47.2	48.6	47.83	47.63	48.76	48.23	50.03	50.06	47.83	49.5	50.53	50.76	53.66	52.76
14	49.93	48.93	48.3	50.93	49.33	49.06	49.33	49.13	48.53	50.2	49.2	49.2	51.03	51.56	51.4
15	47.8	48.23	48.7	47.3	48.23	49.4	48.4	49.36	49	49.33	49.93	49.76	50.56	51.36	51.16
16 ..	48.06	48.03	48.03	47.9	48	48.56	48.26	48.66	48.46	48.8	48.9	48.93	49.53	50.3	50.6
17 ..	49.93	48.33	47.6	47.1	48.3	47.53	48.26	48	47.53	49.33	48.03	48.06	48.96	49.13	49.33
18	48.1	47.9	47.85	49.65	48.8	47.8	49.2	48.35	47.1	49.15	48.6	48.15	49.2	48.65	49.05
20 ...	52.8	51.26	49.8	52.6	50.96	49.86	51.16	49.96	49.03	52.46	50.83	49.8	51.6	49.8	49.26
21.	56	53.93	50.83	56.66	53.33	50.76	54.06	51.26	49.33	55.26	51.8	50.73	53.8	51.36	49.53
22 ...	60.06	57.1	53.06	61.6	56.8	53.1	57.56	53.5	59.8	59.03	54.4	52.43	56.93	52.5	50.73
23 ...	64.4	60.73	55.5	65.76	60.6	55.76	61.06	56.1	52.16	63.1	57.46	54.43	60.83	53.83	51.66
24 ..	65.53	62.93	58.3	65.53	62.23	57.63	63.8	59.16	54.16	65.43	60.33	56.96	64.23	57.8	54.43
25.	63.9	60.9	57.53	64	60.26	57.2	61.63	58.8	55.36	63.46	59.66	57.2	63.13	58.63	54.96
27	65.6	63.83	60.	65.26	62.76	59.5	65.1	61.6	57	65.93	62.16	59.26	65.83	60.83	56.83
28	64.16	62.86	59.7	63.53	62.1	59.46	64.56	61.5	57.86	64.86	62.03	59.7	66.3	61.76	58.06
29.	59.3	59.66	58.86	58.48	58.86	58.53	61.06	60.81	58.06	60.76	60.63	59.43	64	62.33	59.16
30	59.93	58.	56.4	60.93	57.86	56.46	58.6	57.63	56.73	59.26	57.6	57.3	60.86	60.43	58.9
31	64.3	61.3	58	64.86	61.26	58.13	61.8	58.86	56.5	63.13	59.46	57.8	62.5	60.4	58.16
Monthly average.	56.07	54.41	52.03	56.11	54.08	52.00	55.07	53.02	50.62	56.00	53.43	51.96	55.61	52.00	50.44

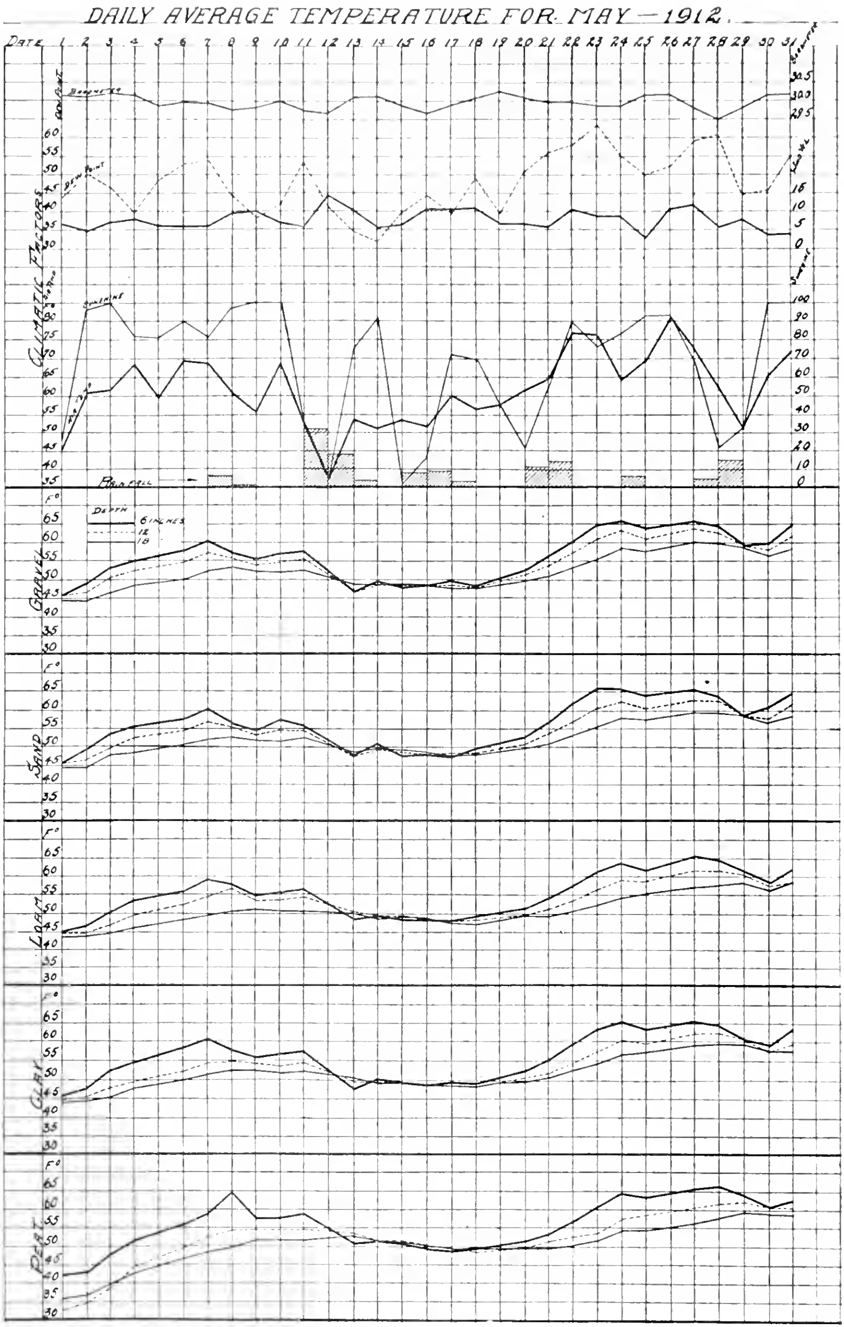
DAILY AVERAGE TEMPERATURE FOR MAY—1912.
DATE
CLIMATIC FACTORS
BAROMETER
DEW POINT
SUNSHINE
RAINFALL
DEPTH
6 INCHES
12
18
GRAVEL
SAND
LOAM
CLAY
PEAT

FIG. 9.

TABLE 24. DAILY AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, JUNE, 1912.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	67.5	64.23	59.73	67.2	63.3	59.63	64.23	61.1	57.1	66.1	61.63	59.26	65.53	60.96	58.3
3	64.76	62.4	59.76	64.86	61.76	59.56	63.43	61.36	58.66	64.3	61.6	60.06	64.9	62.13	59.4
4	64.53	63.06	60.56	64.13	62.43	60.23	64.06	62.26	58.93	64.66	62.33	60.53	66.3	62.8	59.9
5	61.9	60.56	59.4	61.6	60.73	59.2	61.13	60.5	58.73	62.06	60.86	59.93	63.93	62.56	60.13
6	65.8	63.2	60.	65.66	62.76	59.9	63.5	60.93	58.33	61.86	61.56	59.86	64.8	62.1	60.03
7	63.6	62.13	60.26	63.	61.23	59.7	62.5	61.26	58.8	63.5	61.76	60.16	63.9	62.16	60.1
8	63.23	61.86	59.96	62.5	60.9	59.46	62.2	60.76	58.66	62.76	61.06	59.9	63.43	61.93	60.06
10	65.7	63.4	60.66	64.53	62.73	60.36	64.23	61.66	59.	64.93	61.83	60.5	64.9	62.16	60.16
11	66.4	64.26	61.3	65.73	63.3	60.8	64.93	62.36	59.66	64.7	62.43	60.86	65.43	62.26	69.06
12	68.53	66.23	62.4	68.16	65.43	62.13	67.5	63.93	60.43	67.96	63.9	61.8	67.56	63.03	60.35
13	67.46	65.4	62.56	66.46	64.26	62.	66.56	64.13	60.93	66.63	64.1	62.23	67.1	63.9	61.06
14	64.6	64.56	62.93	63.6	63.26	62.2	65.43	64.33	61.43	65.13	64.23	62.7	66.8	64.16	61.9
15	65.9	63.73	61.4	65.86	63.26	60.96	64.9	62.5	60.56	65.3	62.53	61.33	65.36	63.26	61.6
17	67.06	65.23	62.86	66.86	64.73	62.46	66.23	64.23	61.36	66.6	64.1	62.53	67.7	64.6	62.
18	65.33	64.2	62.6	64.6	63.3	62.03	65.06	63.83	61.26	65.03	63.8	62.5	66.5	64.56	62.06
19	66.66	64.9	62.5	66.13	64.03	61.9	65.8	63.53	61.03	64.9	63.5	62.06	66.26	64.06	62.1
20	66.26	64.63	62.5	65.7	63.76	61.93	65.46	63.53	61.16	65.63	63.43	62.1	66.13	64.03	62.03
21	67.13	65.43	63.1	66.5	64.5	62.46	66.33	64.16	61.86	66.33	64.03	62.56	66.96	64.3	62.3
22	68.06	66.13	63.36	67.26	64.96	62.9	67.06	64.56	61.93	66.96	64.4	62.96	67.36	64.73	62.4
24	70.46	68.76	65.53	69.33	67.33	64.76	70.0	66.73	63.16	69.	66.4	64.4	70.2	66.16	62.05
25	71.6	69.	65.56	70.23	67.53	64.73	70.26	66.8	63.7	70.53	66.6	61.73	70.33	66.66	63.83
26	72.73	70.43	66.73	71.03	68.8	65.63	71.66	68.06	64.13	71.33	67.7	65.4	71.93	67.53	64.13
27	71.6	69.93	66.83	70.26	68.4	65.8	71.2	68.43	64.9	70.9	68.03	65.93	71.93	68.36	65.03
28	72.33	69.86	66.66	70.73	68.33	65.7	71.53	68.26	64.9	71.23	67.86	65.9	72.06	68.56	65.36
29	72.33	70.	66.56	71.06	68.66	65.56	71.6	68.1	64.46	71.53	67.76	65.6	72.4	68.2	64.83
Monthly average.	**67.25**	**65.33**	**62.61**	**66.52**	**64.39**	**62.08**	**66.28**	**63.38**	**61.00**	**66.51**	**63.89**	**62.24**	**67.15**	**64.24**	**61.64**

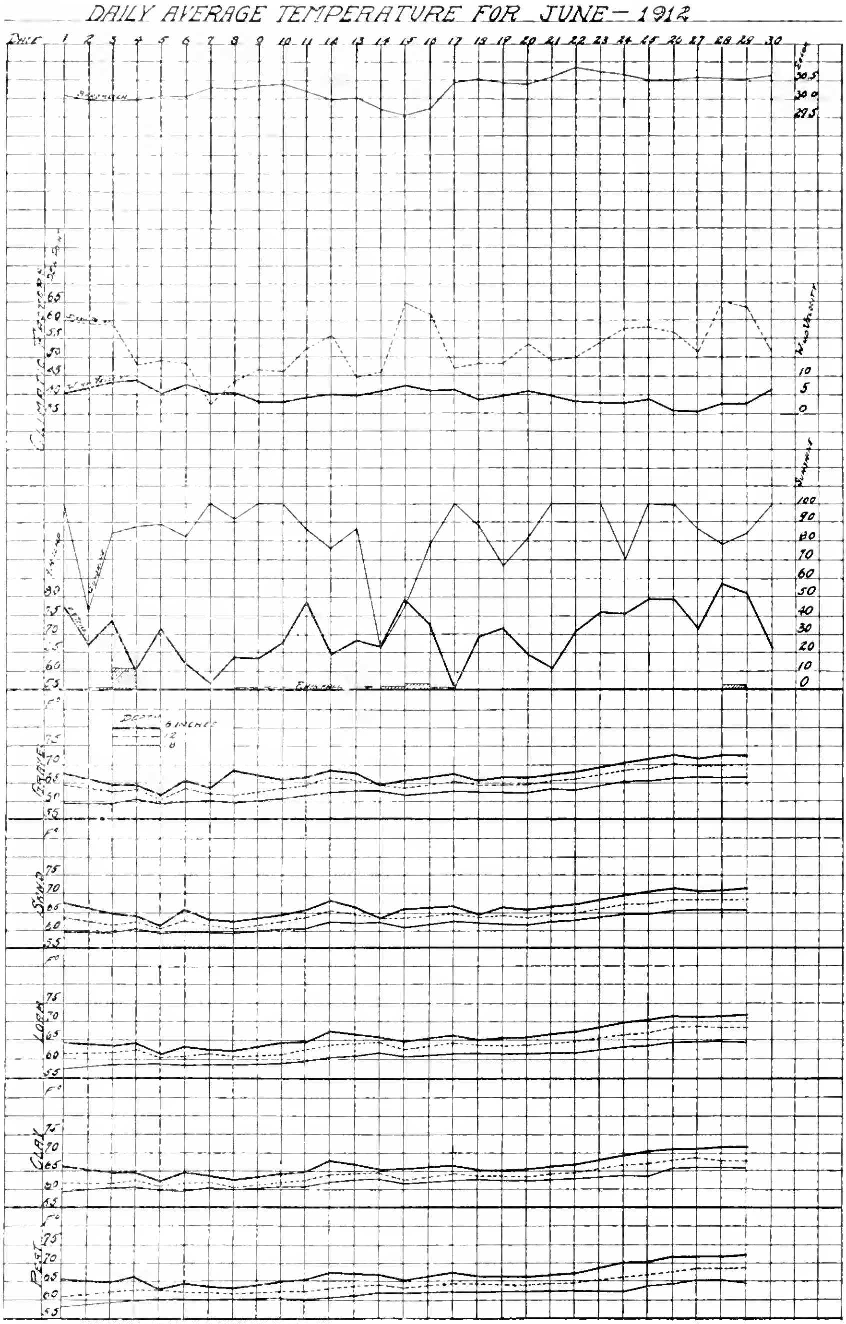
DAILY AVERAGE TEMPERATURE FOR JUNE—1912
DATE
BAROMETER
CLIMATIC FACTORS
HUMIDITY
SUNSHINE
RAINFALL
DEPTH 6 INCHES
12
18
GRAVEL
SAND
LOAM
CLAY
PEAT

FIG. 10.

TABLE 25.—DAILY AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOILS, JULY, 1912.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"
1	71.33	69.66	67.46	69.63	68.	66.23	70.9	69.73	65.8	70.53	68.8	67.13	72.43	70.2	66.6
2	72.73	70.46	67.23	71.26	68.76	66.06	71.9	68.8	65.4	71.53	68.33	66.26	72.76	69.53	66.66
3	75.13	72.66	69.06	73.3	70.86	67.86	74.26	70.6	66.73	74.06	70.16	67.9	75.03	70.73	67.2
4	75.1	72.43	68.76	73.16	70.56	67.6	74	70.46	66.4	73.9	69.96	67.7	74.83	70.5	66.73
5	76.66	74.2	70.2	74.93	72.36	68.73	76.06	71.76	67.33	75.56	71.2	68.56	76.36	71.3	67.16
6	77.3	75	71.2	75.56	73.23	69.93	76.96	73.1	68.73	76.33	72.26	69.63	77.23	72.6	68.26
8	75.56	73.26	70.23	74.76	72.13	69.4	75.1	72.1	68.83	74.9	71.6	69.83	76.36	73.03	69.7
9	77.63	74.63	70.93	76.36	73.26	69.93	76.36	72.46	68.76	76.23	72.03	69.96	77.23	73.13	69.53
10	78.73	76.63	72.73	77.2	75.16	71.76	78.33	74.4	70.13	77.23	74	71.4	79.23	74.33	70.43
11	79.26	76.8	73.33	77.4	75.13	72.16	78.86	75.06	71.06	76.93	74.73	72.23	79.33	75.36	71.5
12	77.9	76.26	73.36	76.16	74.46	72.2	77.43	75.26	71.26	77.03	74.4	72.2	78.83	75.73	71.9
13	75.06	74.86	73.2	73.96	73.63	72.06	76.46	75.13	71.63	75.33	74.16	72.5	78.1	75.7	72.23
15	77.16	75.13	72.13	77.16	74.8	71.66	76.36	73.5	70.2	77.1	73.5	71.33	77.26	74.16	71.4
16	72.66	71.73	71.06	71.6	70.73	70.3	73.13	72.76	70.5	72.86	72.3	71.36	74.7	73.9	71.46
17	76.53	74.1	71.43	76.	73.3	70.8	75.43	72.56	69.86	75.26	72.16	70.66	75.73	73.16	70.93
18	72.63	72.93	72.16	71.03	71.63	71.26	74.1	73.5	70.5	72.9	72.83	71.46	75.83	73.9	71.13
19	66.43	66.5	67.66	65.8	65.83	66.9	67.8	69.56	69.	67.13	68.56	69.03	70.23	71.96	70.63
20	65.36	66	66.73	64.63	65.53	66.43	67.1	68.16	67.23	66.53	67.56	67.5	69.56	70.33	69.60
22	66.53	65.2	64.66	67.16	65.3	64.6	65.86	65.3	64.9	66.23	65.	65.06	66.3	66.93	66.96
23	67.33	66.6	65.86	68.	66.96	66.06	67.13	66.1	64.86	67.83	66.33	65.6	67.7	66.7	66.13
24	70.	68.03	66.06	70.23	68.06	66.1	68.6	66.5	65.03	69.43	66.76	65.83	68.2	66.53	65.73
25	72.6	70.46	67.86	73.06	70.56	65.9	71.26	68.4	65.93	72.23	68.7	67.03	70.93	67.8	66.16
26	69.96	69.3	68.33	69.86	69.16	68.23	70.06	69.26	66.83	70.7	69.46	68.13	70.53	69.4	67.
27	69.43	67.8	66.53	69.2	67.36	66.33	68.76	67.63	65.86	69.3	67.63	66.8	68.8	68.	66.63
29	68.33	68.	67.3	67.86	67.36	67.3	69.16	68.8	67.06	68.93	68.05	67.73	70.	69.23	67.8
30	66.7	66.53	66.46	66.36	66.36	66.43	67.43	67.6	66.56	67.6	67.53	67.16	68.96	68.96	67.86
31	65.66	65.36	65.6	65.43	65.	65.46	66.	66.4	65.9	66.13	66.33	66.2	67.53	68.	67.43
Monthly average...	**72.56**	**71.11**	**69.16**	**71.74**	**70.20**	**68.49**	**72.40**	**70.55**	**67.86**	**72.20**	**70.15**	**68.74**	**73.30**	**68.56**	**68.70**

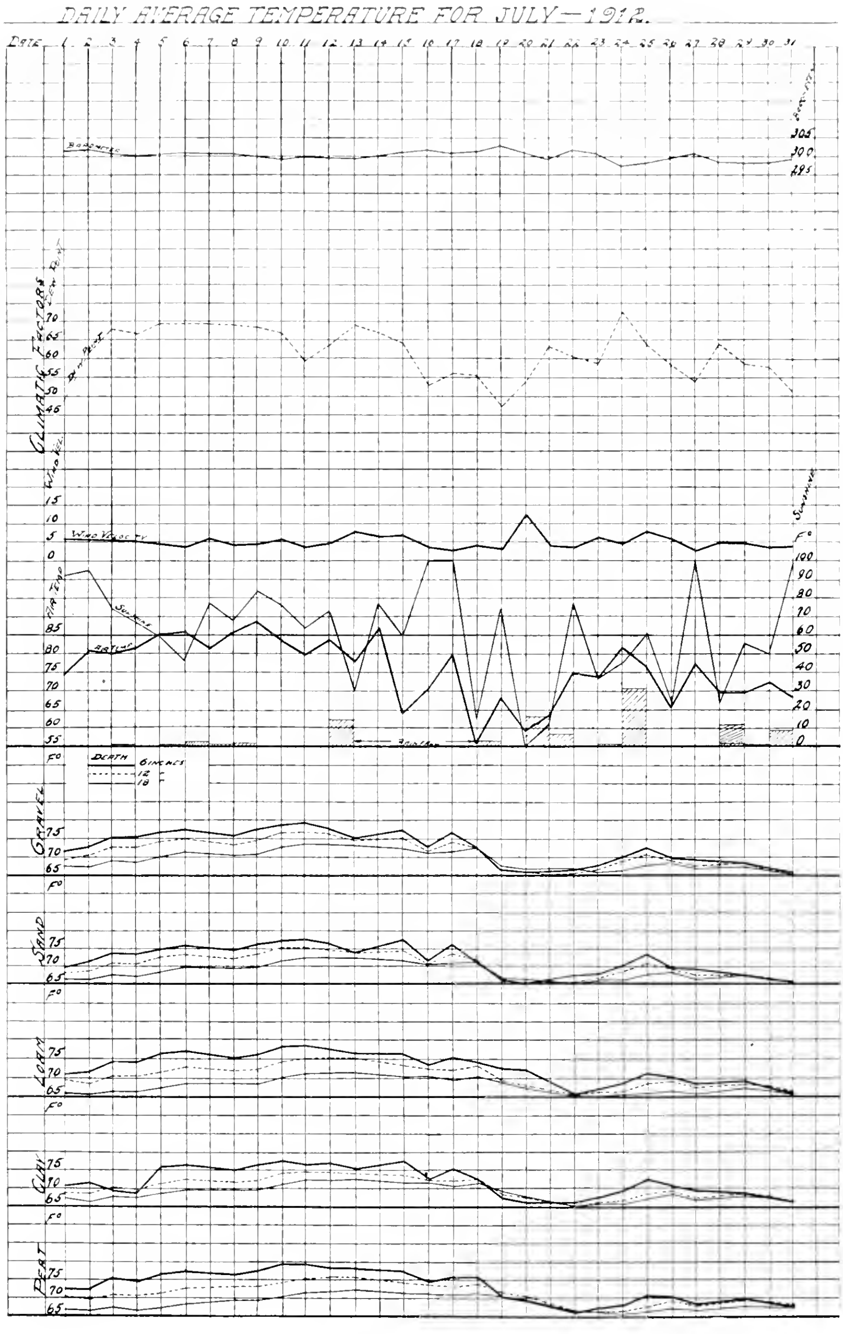
DAILY AVERAGE TEMPERATURE FOR JULY—1912.
Date
Barometer
Climatic Factors
Dew Point
Wind Vel.
Wind Velocity
Sunshine
Air Temp.
Rainfall
Depth 6 inches
12
18
Gravel
Sand
Loam
Clay
Peat

FIG. 11.

TABLE 26.—DAILY AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, AUGUST, 1912.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1 ...	65.1	64.53	64.83	65.23	64.66	64.86	64.86	65.36	65.03	65.63	65.5	65.53	66.36	66.93	66.6
2 ...	65.13	65.0	64.93	64.53	64.63	64.86	65.33	65.3	64.53	65.53	65.43	65.23	65.96	66.06	66.0
3 ...	61.1	61.73	63.26	60.66	61.43	63.	62.13	63.8	63.93	61.9	63.53	64.86	63.7	65.3	65.4
5 ...	66.43	64.9	63.73	66.66	64.83	63.76	64.96	63.73	62.86	65.76	63.9	63.43	61.86	64.	64.13
6 ...	67.96	66.56	65.03	67.9	66.33	64.96	66.9	65.13	63.6	67.36	65.36	64.4	66.46	64.7	64.06
7 ...	69.43	68.03	66.03	69.4	67.7	65.96	68.53	66.36	64.53	69.0	66.53	65.36	68.03	65.56	64.6
8 ...	69.76	68.2	66.26	69.73	67.86	66.06	68.96	67.0	65.	69.36	67.06	65.93	68.8	66.3	64.96
9 ...	69.53	68.43	66.6	69.33	67.93	66.76	69.36	67.43	65.13	69.63	67.86	66.06	69.73	66.66	65.
10 ...	67.66	67.	66.2	67.56	66.7	65.5	68.03	67.2	65.43	68.03	66.93	66.13	68.86	67.2	65.8
12 ...	67.73	66.4	65.13	68.06	66.23	65.03	67.1	65.9	64.63	67.4	65.73	65.23	67.66	66.56	65.73
13 ...	71.0	69.03	66.46	72.03	69.20	66.53	69.6	66.86	64.83	70.6	67.13	65.8	70.1	66.9	65.43
14 ...	72.66	70.73	68.16	72.8	70.43	67.86	71.36	68.66	65.86	72.26	68.96	67.13	71.73	68.13	65.93
15 ...	69.96	69.5	68.43	69.46	68.76	67.9	70.3	69.3	66.73	70.26	69.2	67.9	71.1	69.16	66.66
16 ...	68.83	68.0	67.2	68.26	67.3	65.03	68.9	68.33	66.53	68.63	68.03	67.26	69.6	68.9	67.1
17 ...	67.33	67.2	66.86	66.73	66.5	66.43	67.9	67.8	66.1	67.36	67.3	66.83	68.93	68.3	67.0
19 ...	70.13	69.33	67.76	69.63	68.8	67.46	70.3	68.53	66.03	69.73	68.36	66.96	70.73	68.2	66.6
20 ...	69.86	68.50	67.06	69.93	67.9	66.76	69.3	67.9	66.1	69.23	67.7	66.83	69.8	68.3	66.66
21 ...	70.13	68.9	67.63	70.66	68.96	67.63	69.83	68.63	66.46	70.1	68.43	67.3	70.46	68.86	67.26
22 ...	69.7	69.2	68.46	69.56	69.06	68.4	70.	69.2	67.33	70.13	69.23	68.23	70.63	69.43	67.96
23 ...	66.43	66.4	66.86	65.73	66.1	66.93	67.1	68.0	66.9	66.93	67.7	67.56	68.26	69.0	67.66
24 ...	66.46	65.26	65.23	66.4	65.0	65.13	65.7	66.03	65.63	66.0	65.73	65.86	66.1	67.36	67.26
26 ...	75.3	73.	69.63	75.1	72.56	69.43	73.7	69.96	66.56	74.16	70.1	67.93	73.3	68.3	66.16
27 ...	71.23	70.76	69.83	70.63	70.1	69.36	71.43	70.73	68.43	71.1	70.36	69.26	72.33	70.3	67.9
28 ...	66.53	67.46	68.26	65.56	66.9	67.8	68.36	69.46	67.9	67.26	68.76	68.4	70.3	69.5	68.33
29 ...	64.46	64.53	65.26	64.1	64.2	64.8	65.26	66.16	65.93	65.	65.63	65.96	68.06	66.53	67.76
30 ...	61.08	61.73	63.26	60.16	61.26	63.03	62.4	64.	64.03	63.53	63.6	64.26	66.13	64.6	66.23
31 ...	65.46	63.4	62.4	62.26	63.5	62.53	63.9	62.96	62.8	64.7	62.8	62.86	64.5	64.03	64.93
Monthly average...	**68.00**	**67.18**	**66.33**	**67.85**	**66.85**	**66.07**	**67.82**	**67.00**	**65.52**	**68.01**	**66.92**	**66.23**	**68.60**	**67.22**	**66.26**


DAILY AVERAGE TEMPERATURE FOR AUGUST-1912
DATE
CLIMATIC FACTORS
BAROMETER
DEW POINT
WIND VELOCITY
AIR TEMP
SUNSHINE
RAINFALL
DEPTH 6 INCHES
12
18
GRAVEL
SAND
LOAM
CLAY
PEAT

FIG. 12.

TABLE 27.—DAILY AVERAGE TEMPERATURES OF DIFFERENT TYPES OF SOIL, SEPTEMBER, 1912.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
2	74.10	71.63	68.60	74.40	71.40	68.33	72.20	68.73	65.80	72.83	69.03	67.13	71.87	67.57	65.43
3	73.67	71.90	69.63	73.70	71.43	69.10	72.93	70.17	67.33	73.20	70.37	68.53	73.33	69.13	66.40
4	72.77	71.67	70.10	72.63	71.27	69.63	73.27	71.20	68.47	72.33	70.83	69.50	73.67	70.73	68.30
5	73.83	72.23	70.03	73.57	71.80	69.90	73.43	71.30	69.07	72.80	70.87	69.63	73.77	71.10	68.97
6	73.90	72.20	70.33	73.93	71.80	69.83	73.53	71.43	69.00	72.63	71.13	69.87	74.07	71.47	69.33
7	74.30	72.43	70.93	74.40	72.57	70.43	74.20	72.03	69.27	73.27	71.73	70.20	75.03	72.00	69.63
9	74.43	72.73	70.47	74.23	72.03	70.10	73.90	71.60	69.10	73.87	71.13	69.80	74.27	71.70	69.77
10	75.63	73.93	71.80	75.03	73.27	71.40	75.10	72.93	70.03	74.20	72.53	71.07	75.53	72.87	70.50
11	73.23	73.03	72.17	72.33	72.13	71.50	74.20	73.27	70.67	73.63	72.70	71.43	74.30	74.43	70.83
12	66.87	67.40	68.73	66.37	66.77	68.23	68.40	70.23	69.73	68.00	69.67	69.97	70.90	71.93	70.97
13	67.20	67.00	67.50	66.67	66.53	67.23	67.97	68.60	68.10	67.47	68.17	68.30	69.97	70.30	70.07
14	66.83	66.73	66.73	66.23	66.30	66.60	67.37	67.73	66.77	67.40	67.37	67.33	68.27	68.73	68.63
16	64.17	64.40	65.50	64.07	64.23	65.23	65.13	66.17	65.93	64.87	65.70	66.03	66.17	67.40	67.53
17	62.23	63.10	64.77	61.63	62.93	64.77	63.80	65.40	65.30	63.30	64.97	65.53	65.27	66.97	67.03
18	61.43	63.53	64.17	61.37	62.83	63.57	63.30	64.00	64.23	63.37	63.67	64.27	63.87	65.30	66.13
19	59.57	60.87	62.80	58.97	60.63	62.77	61.03	63.27	63.70	60.23	62.80	63.67	62.47	64.63	65.53
20	59.43	59.57	61.10	58.97	59.53	61.23	59.50	61.50	62.43	59.33	60.77	62.07	60.33	62.87	64.53
21	61.53	60.83	61.43	62.07	61.30	61.37	60.87	61.23	61.50	61.10	61.17	61.63	60.97	62.00	63.27
23	59.80	60.00	61.40	59.20	59.70	61.37	60.23	61.40	62.00	61.37	61.00	61.90	60.17	61.90	63.13
24	59.27	59.10	60.67	58.70	59.23	60.37	59.37	60.47	60.83	59.13	60.27	60.73	59.17	60.57	61.90
25	61.10	60.57	61.00	61.23	60.50	60.93	61.17	60.73	60.70	61.80	60.77	61.00	60.77	60.67	61.53
26	60.50	61.40	62.00	60.47	61.23	62.10	61.13	61.83	61.47	61.30	61.90	62.10	61.37	61.53	61.90
27	55.30	56.43	59.23	54.10	55.93	58.97	56.23	59.70	60.23	55.80	59.43	60.37	56.50	60.23	61.27
28	53.33	54.97	57.37	52.63	54.90	57.70	54.67	57.43	59.00	51.20	57.10	58.67	55.27	59.07	60.93
30	51.03	52.13	54.47	50.63	51.93	54.90	51.47	54.43	56.23	51.40	51.00	55.83	51.90	55.67	58.57
Monthly average	**65.40**	**65.20**	**65.33**	**65.08**	**64.88**	**65.08**	**65.76**	**65.82**	**65.08**	**65.56**	**65.56**	**65.46**	**66.37**	**66.44**	**66.08**

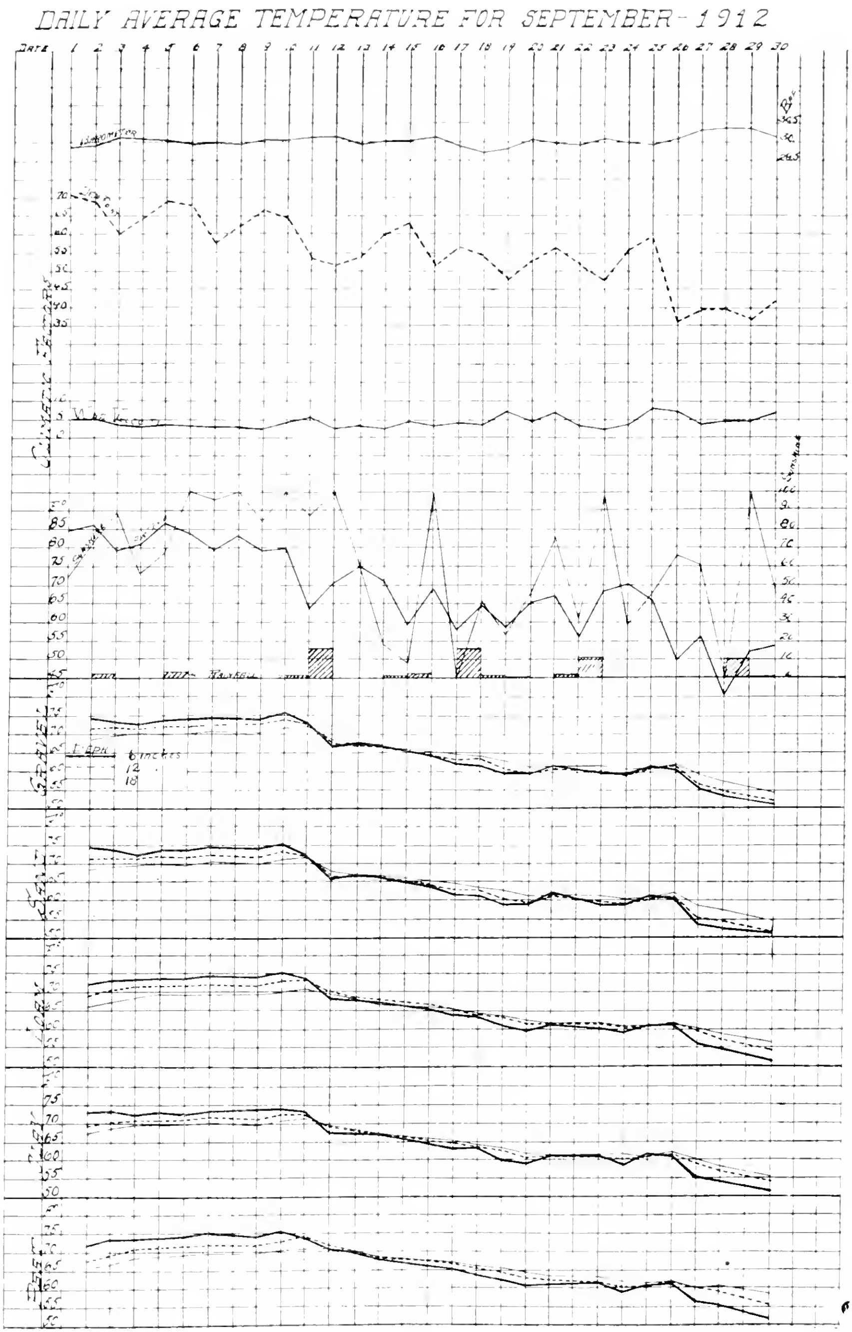
DAILY AVERAGE TEMPERATURE FOR SEPTEMBER - 1912
DATE
Barometer
Depth
6 inches
12
18
Rainfall

FIG. 13.

TABLE 28. DAILY AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, OCTOBER, 1912.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"
1	53.50	52.90	54.53	52.20	53.00	51.53	55.63	53.93	55.36	52.60	53.66	55.33	51.83	54.80	58.17
2	53.53	53.53	54.96	53.53	53.46	55.16	52.73	54.90	55.23	53.20	54.40	53.36	52.03	54.46	57.33
3	53.20	54.20	55.00	52.46	54.26	55.40	53.20	57.60	55.10	53.16	54.60	55.56	52.73	54.30	56.43
5	56.03	59.06	56.03	56.33	55.86	55.03	54.76	55.00	55.26	55.46	55.40	54.89	54.36	54.70	55.63
7	59.03	58.83	58.20	59.03	58.73	58.26	58.60	57.56	56.63	59.00	57.96	57.33	57.73	55.63	56.36
8	52.90	54.83	57.13	52.03	54.06	56.43	54.10	57.13	57.03	53.90	56.50	57.70	54.70	56.36	56.93
9	51.56	52.23	53.30	51.26	52.06	54.03	52.03	54.23	55.33	52.36	53.90	54.50	52.30	54.86	56.36
10	53.76	54.13	54.93	53.63	54.13	55.10	53.83	54.76	55.10	53.76	54.56	55.16	53.76	54.76	56.36
11	55.80	54.96	54.93	55.40	55.10	55.16	54.56	54.70	54.96	55.20	54.66	54.93	54.16	54.66	56.06
12	56.06	56.26	56.26	55.66	56.26	56.56	56.30	55.76	55.56	56.33	56.40	56.20	56.23	55.36	56.43
15	49.16	49.90	51.93	49.26	50.20	52.73	49.36	51.60	53.10	49.80	51.40	52.90	49.56	52.76	55.00
16	46.83	48.00	50.43	46.93	48.40	50.97	47.07	49.90	51.67	47.27	49.67	51.50	47.43	50.73	54.00
17	48.60	48.90	50.47	48.57	49.03	51.00	48.00	49.93	51.33	48.20	49.50	51.13	47.37	50.23	53.23
18	52.27	51.60	52.03	52.63	52.03	52.13	50.63	51.00	51.63	51.67	50.70	51.57	49.50	50.20	52.93
19	50.20	50.93	51.30	49.87	51.97	51.80	51.50	51.17	52.03	50.97	52.03	52.43	51.03	50.47	52.60
21	49.47	49.57	50.70	49.33	49.70	51.30	50.50	49.03	51.77	49.57	50.30	51.60	48.83	50.93	53.30
22	52.30	52.87	52.73	53.83	53.00	52.77	51.50	52.57	51.97	52.53	51.77	51.87	51.40	50.37	52.37
23	47.10	49.13	51.27	46.80	49.17	50.90	49.97	49.50	51.53	48.30	50.83	51.47	49.53	50.00	51.67
24	44.70	46.30	49.60	44.20	46.37	49.80	48.70	46.37	51.60	45.23	48.93	50.83	47.83	50.63	52.10
25	44.30	45.57	48.13	44.37	45.43	48.47	47.13	45.23	50.00	44.50	47.89	49.40	45.87	49.80	52.03
26	45.33	45.97	48.07	45.40	46.33	48.80	44.97	47.40	49.33	45.37	47.30	48.87	45.30	48.53	51.30
28	46.93	46.96	48.20	46.83	47.30	48.63	45.73	47.07	48.67	46.30	47.20	48.40	45.57	47.10	49.87
29	48.86	48.76	49.33	48.96	48.93	49.66	47.50	48.30	48.96	48.23	48.13	49.03	46.66	47.40	49.73
30	45.80	47.16	49.16	45.33	47.73	49.26	46.30	48.43	49.16	46.33	48.43	49.10	46.80	47.76	49.73
31	41.56	43.66	47.13	40.66	43.46	47.80	42.80	46.76	48.83	42.63	46.70	48.46	44.40	47.43	49.40
Monthly average.	50.38	51.05	52.25	50.16	51.05	52.37	50.68	51.48	52.69	50.48	51.48	52.61	50.28	51.77	53.80

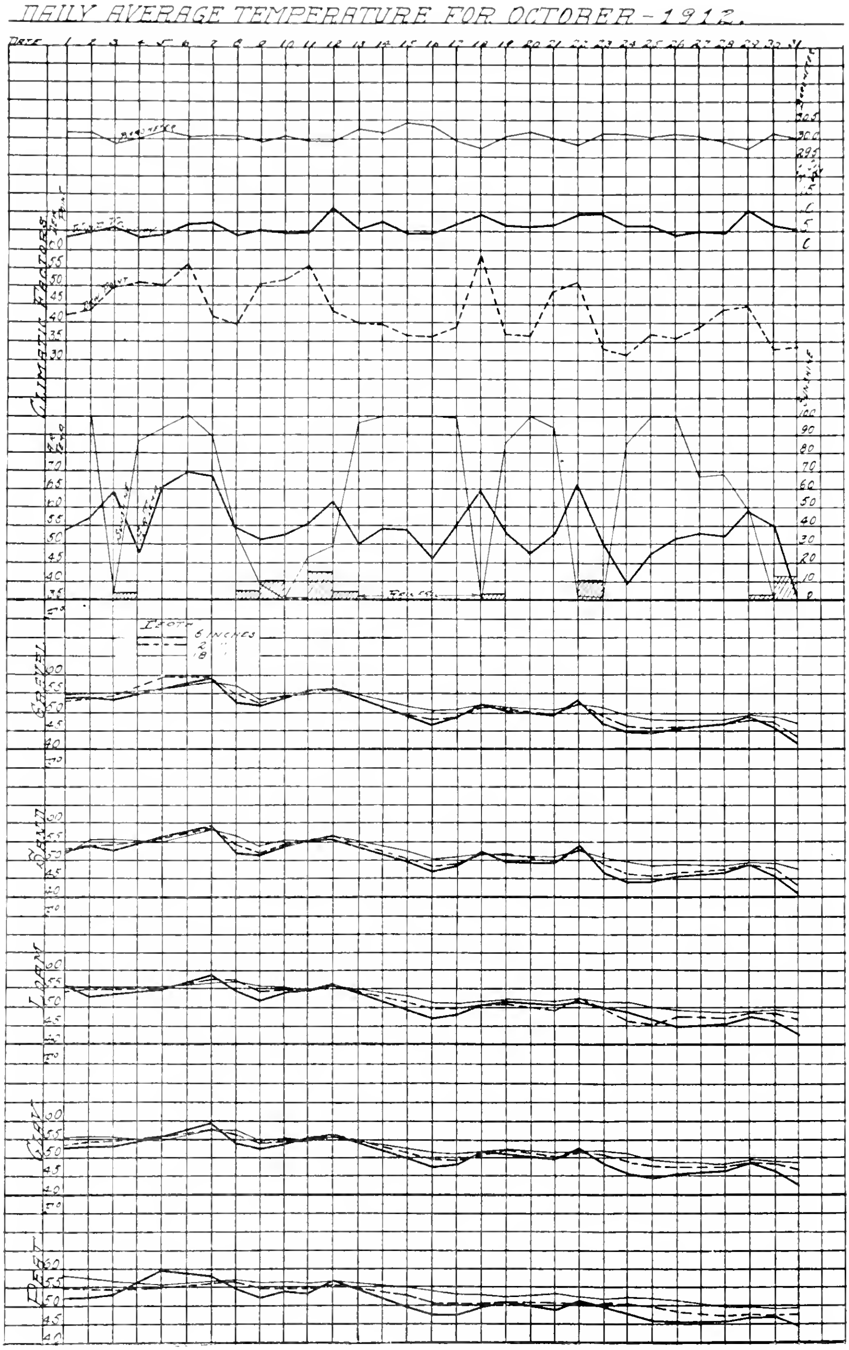
DAILY AVERAGE TEMPERATURE FOR OCTOBER—1912.
DATE
CLIMATIC FACTORS
BAROMETER
DEW POINT
FOG
ISOTH
6 INCHES
2 "
18 "
GRAVEL
SAND
LOAM
CLAY
PEAT

FIG. 14.

TABLE 29.—DAILY AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOVEMBER, 1912.

Date.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1........	38.30	41.06	44.86	37.90	41.30	45.43	40.10	41.50	47.43	39.60	44.23	46.56	41.90	46.46	49.33
2........	36.87	38.97	43.03	36.17	38.97	43.33	37.90	42.43	45.73	35.77	42.17	44.73	39.40	44.43	48.47
4........	37.97	39.10	42.03	37.53	39.30	42.67	37.63	40.90	43.90	38.00	40.87	43.00	37.20	41.67	45.67
5........	42.10	42.17	43.30	42.37	42.60	43.87	40.70	41.87	43.80	41.27	42.00	43.40	38.63	41.10	44.97
6........	47.27	46.67	46.10	47.50	47.27	46.27	45.47	44.53	44.83	46.33	45.03	45.07	42.97	41.87	44.53
7........	45.50	46.17	47.00	45.30	46.23	47.13	45.27	46.00	45.97	45.77	46.27	46.60	44.37	43.53	44.87
8........	42.60	43.53	45.73	42.43	43.43	45.77	42.70	44.83	46.27	42.70	44.90	46.13	42.43	43.90	45.13
9........	42.00	43.03	45.13	42.03	43.37	45.60	42.10	44.37	46.10	42.23	44.33	45.70	42.10	43.97	45.97
11........	45.17	44.73	45.10	45.30	44.83	45.47	43.67	44.13	45.27	44.17	44.07	45.13	42.27	43.17	45.50
12........	49.50	48.73	47.27	49.73	48.77	47.33	47.87	46.53	46.10	48.03	46.77	46.37	45.83	44.17	45.70
13........	50.50	50.40	49.43	50.30	50.20	49.40	50.10	49.07	47.83	50.57	49.30	48.53	48.57	46.17	46.43
14........	41.53	44.10	47.60	40.80	43.93	47.50	43.73	47.30	48.30	43.77	47.07	48.27	45.33	46.90	46.50
15........	37.97	40.43	44.53	37.57	40.67	44.90	39.53	44.13	46.90	39.03	43.60	45.90	41.93	45.90	47.90
16........	35.90	38.33	42.70	35.57	38.70	43.17	37.23	41.83	44.80	36.87	41.30	43.70	39.27	43.80	46.93
18........	37.93	39.07	41.87	37.37	39.13	42.27	37.47	40.30	42.90	37.80	40.27	42.27	37.63	41.07	44.33
19........	38.83	39.67	41.93	38.63	39.77	42.23	38.07	40.37	42.77	38.53	40.47	42.13	37.70	40.33	43.93
20........	39.03	39.37	42.13	38.70	39.37	42.40	38.27	40.87	42.43	38.47	41.03	42.37	38.20	40.40	43.43
21........	41.27	41.37	42.30	41.43	41.67	42.63	40.33	41.00	42.27	40.60	41.37	42.07	39.03	39.67	42.50
22........	38.27	39.67	42.37	38.03	40.10	42.73	38.80	41.53	42.90	38.60	41.57	42.73	39.10	40.50	42.77
23........	36.90	38.55	41.60	36.75	38.85	41.95	37.55	40.60	42.50	37.35	40.50	42.20	38.10	40.50	42.95
25........	35.83	37.37	40.17	35.40	37.60	40.77	35.97	39.00	41.70	36.07	38.97	41.03	36.67	39.73	42.77
26........	34.73	36.30	39.10	34.23	36.50	39.73	34.97	38.00	40.60	35.00	37.90	39.90	35.63	38.60	41.93
27........	34.87	36.30	38.97	34.57	36.40	39.43	34.87	37.83	40.30	34.90	37.73	39.60	35.47	38.40	41.63
29........	35.45	36.70	39.40	35.00	37.50	39.90	35.35	38.15	41.30	35.45	38.00	39.85	35.85	38.55	41.80
30........	34.87	36.30	38.73	34.50	36.43	39.40	34.80	35.70	40.10	35.00	37.70	39.27	35.20	37.87	41.13
Monthly average.	**40.44**	**41.13**	**43.32**	**39.80**	**41.32**	**43.67**	**40.00**	**42.28**	**44.12**	**40.80**	**42.29**	**43.70**	**40.00**	**42.11**	**44.68**

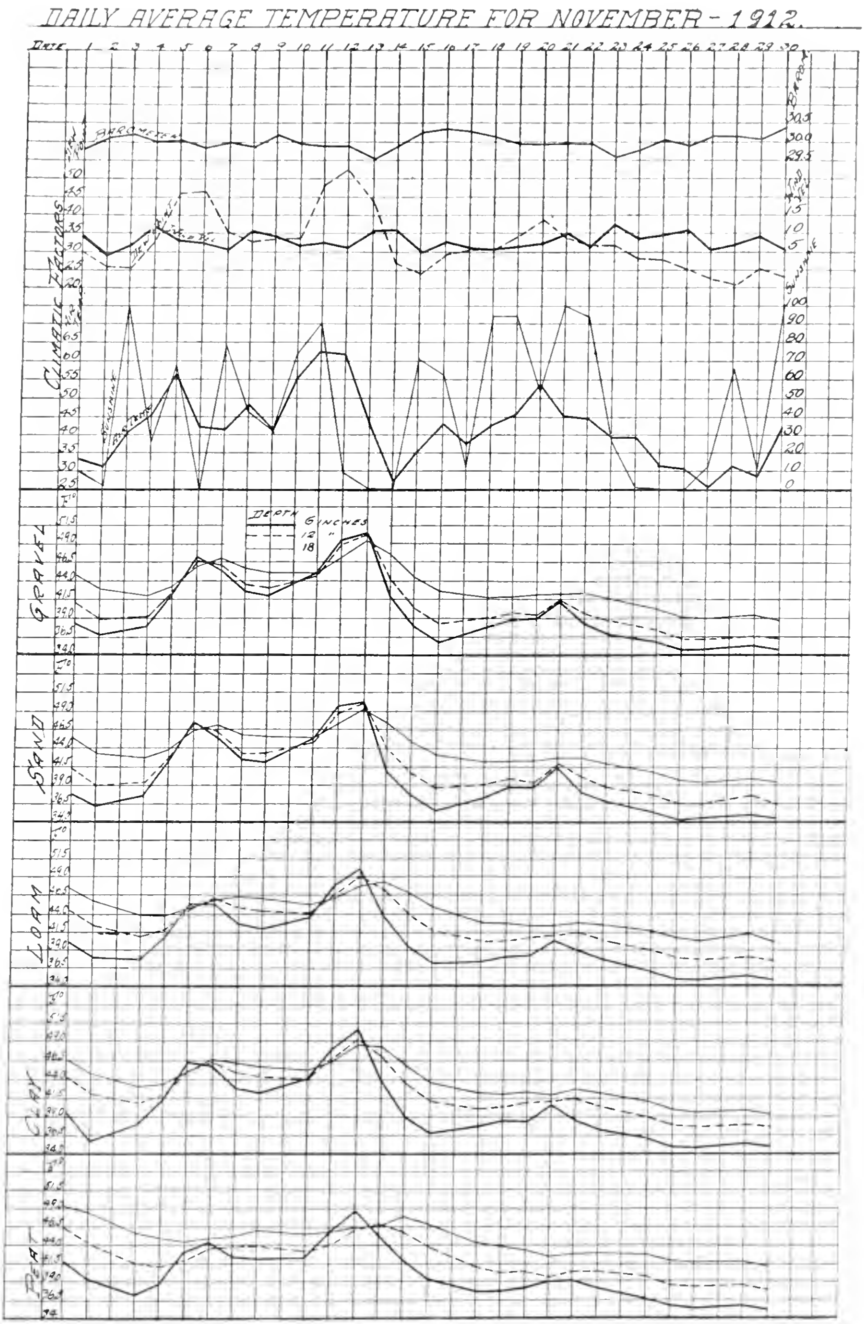
DAILY AVERAGE TEMPERATURE FOR NOVEMBER - 1912.
DATE
CLIMATIC FACTORS
BAROMETER
SUNSHINE
GRAVEL
SAND
LOAM
CLAY
PEAT
DEPTH 6 INCHES
12 "
18

FIG. 15.

Before entering into the discussion of the foregoing results, the reader should be reminded again that all these different types of soil were covered with a thin layer of a sandy soil in order to eliminate the factor of color as this factor was investigated in a separate experiment, the results of which will be presented subsequently.

The thin layer of the sandy soil, besides giving the different soils about the same shade of color, tended also to equalize the rate of evaporation of their moisture. Both color and evaporation have a very marked influence upon the soil temperature. If these different soils, therefore, had not been covered with the thin layer of the sandy soil, probably somewhat different results might have been obtained as indicated by the data of the experiment on the effect of different amounts of organic matter on soil temperature—later to be presented. The temperature of these different soil types, however, uncovered, is now being investigated and the data will be reported later.

With these facts in mind a detailed discussion of the foregoing results is now in order.

Beginning with the middle of November it is found that the daily average temperature of the different types of soil runs somewhat in this manner: The temperature at all three depths of all the different soils decreased gradually until December 1 when the upper 6 inches of every soil froze. They all stayed frozen for a few days, then thawed and froze again the latter part of December. About this time the lower depths also began to freeze. The 12-inch depth of the gravel froze December 29, of the sand December 30, of the loam January 1, of the clay January 2, of the peat January 2. The 18-inch depth of the gravel and sand froze January 3, of the clay January 9, of the loam January 12, and of the peat January 20. None of the temperatures of any of the depths of any of the soils remained at the freezing point but continued to fall rapidly until a minimum was reached and then began to rise again. At the depth of 6 inches the average minimum was reached for gravel January 6 with 19.96° F., for sand January 6 with 11.73°, for loam January 8 with 21.86°, for clay January 8 with 21.7°, and for peat January 8 with 19.63°. At the depth of 12 inches the lowest average temperature was reached for gravel January 8 with 23.96°, for sand January 8 with 23.00°, for loam January 15 with 28.6°, for clay January 17 with 27.13°, and for peat January 13 with 27.8°. At the depth of 18 inches, the average minimum was attained for gravel January 13 with 29.7°, for sand January 17 with 30.1°, for loam January 20 with 30.5°, for clay January 22 with 29.83°, and for peat January 30 with 30.76°. The rising in every case was gradual, varying slightly from day to day and tending to attain the freezing point, but was below this throughout the cold period. Up to February 19 the temperature of the upper 6 inches fluctuated near 28.0°, then rose to about 30.0° and remained near that point till thawing commenced. The temperature of the 12-inch depth rose shortly after the minimum was attained to about 29.0° and stayed near that temperature until about the middle of February, then rose to about 30.0° F. and remained at about that point also till thawing took place. The temperature of the 18-inch depth of all the soils ranged near 30.0° to 31.0° F. from the time the lowest temperature took place till the thawing

period. The thawing commenced about the beginning of April. The various soils and the different depths within the same soil thawed at different dates. The 6-inch depth of the gravel and sand thawed April 5, of the clay April 6, of the loam April 7 and of the peat April 15. The 12-inch of the gravel thawed April 5, of the sand April 6, of the clay April 10, of the loam April 13 and of the peat May 1. The 18-inch depth of the gravel and sand thawed April 7, of the clay April 12, of the loam April 15, and of the peat April 24.

Immediately after the commencement of thawing, the temperature of the different soils at the 6-inch depth began to rise quite rapidly but at different rates. The temperature of both the gravel and sand rose far above that of the other soils, followed by clay, loam, and peat respectively. This order of magnitude continued until all the lower depths of the heavier soils thawed, then their temperature rose rapidly and approached that of the lighter soils. The time that it took the heavier soils to attain the same temperature as the lighter soils at the 6-inch depth varied with the soil, for the clay it was 11 days (April 16), for the loam 12 days (April 17), and for the peat 32 days (May 6), from the date the upper 6 inches of the gravel and sand began to thaw. From these dates on, the temperature of the upper surface of all the soils ran about the same.

The temperature of all the soils at all three depths continued to rise till July when the maximum temperature was attained, and then began to fall. At the depth of 6 inches the highest average temperature for all soils was reached on July 11 with the following magnitude: gravel 79.26°, sand 77.4°, loam 78.86°, clay 76.73°, peat 79.33°. At the depth of 12 inches the highest average temperature was attained for gravel on July 11 with 76.8°, for sand July 10 with 75.16°, for loam July 12 with 75.26°, for clay July 11 with 74.73°, and for peat July 12 with 75.73°. While at the depth of 18 inches the highest average temperature is shown by gravel and sand on July 12 with 73.36° and 72.2°, respectively, by loam July 13 with 71.63°, by clay July 13 with 72.5°, and by peat July 13 with 72.23°. From these dates on, the temperature of all the soils at all three depths fell irregularly but gradually till freezing.

The data for the second year, or cycle, are not presented here but they are on file and show that as far as they go they confirm the first year's results perfectly. The first freezing, for instance, occurred about the middle of December, and as in the previous year the upper 6 inches of all the soils froze about the same time as shown by the following dates: Gravel and sand Dec. 12, loam and clay Dec. 13, and peat Dec. 14. All these soils remained frozen at this depth until Dec. 18th when they all thawed and froze again Dec. 23. The 12-inch depth of the gravel and sand froze Feb. 3, of the clay and loam Feb. 5, and of the peat Feb. 6, while the 18-inch depth of the gravel froze Feb. 6, of the sand Feb. 8, of the loam Feb. 11, of the clay Feb. 10 and of the peat Feb. 23. The lowest average temperature that all the different soils reached at the upper 6-inch depth was on Feb. 13, with the following results: Gravel 22.43° F., sand 19.60°, loam 23.30°, clay 23.93°, and peat 20.50°. In the spring all these soils thawed in the same order as in the first spring.

Thus far the daily march of average temperature for the five different kinds of soils has been given without any comment or explanation of the results. It will not be well to discuss the foregoing data in a brief manner and emphasize the most important and essential facts. After this the consideration of the meteorological elements and their influence upon the foregoing results will be in order.

One of the most important facts that needs emphasis is the rate at which all the different types of soil cooled and froze at the upper 6-inch depth. It is a common belief, and a logical one, that the lightest soils cool the fastest and the heaviest soils the slowest, and warm up in the some order. The preceding data, however, show very conclusively that the gravel and sand at the upper 6-inch depth cooled and froze about the same time as the clay, loam and peat.

In the spring the two light soils thawed at the upper depth first and both at the same time, followed by clay, one day later, loam two days later, and peat ten days later, and that the temperature of the light soils rose and remained far above that of the heavy soils, for some time.

The question now is why should there be this anomaly or disagreement. The explanation may be found, as will be subsequently given, in the difference in the moisture content of the various soils and in the fluctuating downward and upward trend of the air temperature in the fall and spring respectively.

As previously stated, the moisture content of these soils was determined at various times of the year. In table 4 are given the determinations of April 3 just before thawing commenced and in November 4 when the rapid cooling began. It is seen that the percentage of the water content varies tremendously among the various soils which in turn affects their specific heat very greatly. As shown in that table (4) 100 heat units or calories will raise the temperature of the soils in the dry condition as follows: gravel, .00895° C. sand .01117°, loam .01401°, clay .01399°, peat .02374°. When the moisture content is also considered then the raise is as follows: gravel .006520° C., sand .005876°, loam .004848°, clay .005690°, peat .002127°. These latter figures show that the temperature of the sand or gravel rises two or three times higher than that of the peat with the same number of heat units. From this we should expect that in the spring the light soils should warm much earlier than the peat soils, and in the fall they should cool in the same order. The foregoing data show that in the spring they do warm up in the order given or in the order of their specific heats, but in the fall they cool almost at the same rate and freeze about the same time.

The difference in the moisture content together with the upward and downward trend of temperature in the spring and fall respectively, account for this disagreement. In the spring the daily march of the air temperature has a continually upward trend. The lighter soils having the lowest specific heat warm up early and their temperature fluctuates as the weather elements vary, but the trend is upward. The heavier soils and especially the peat having the greatest heat capacity warm up slowly but gradually and finally reach the same temperature as the lighter soils. In the fall the trend of the air temperature is downward as is also that of the soils. On certain days the air temperature falls very low, whereupon all the soils are cooled, the light soils the most

and the heavy soils the least; next day the air temperature rises considerably and the temperature of the soils rises according to their specific heat: the light soils attain the highest temperature as in the spring, and the heavier soils the lowest; another day follows with very low temperature whereupon all the soils lose heat again in the same order as above: the sand and gravel as usual lose more than the other soils, but they attained a higher temperature during the day time and consequently have more apparent heat to lose. These alternate cold and warm days with the downward trend of air temperature tend to keep the lighter soils as warm as the heavier soils.

If the air temperature would continue to drop very rapidly without any warm days intervening, then the light soils would cool or freeze most rapidly and would continue to have a much lower temperature. This is well illustrated whenever a severe cold weather sets in as on January 8, 1911, when the coldest day of the year occurred and the soil temperature dropped very low. On this date the light soils cooled the most and the heavy soils the least. It is in such occasions or circumstances as these that high moisture content becomes an advantage and renders highly practical benefits.

The next most interesting fact that the foregoing tables and charts show is the same magnitude of temperature in the upper 6 inches of all the different types of soil at all times except during thawing. Here again it is the common belief that the light soils, for the same reason that they warm up the fastest in the spring and cool most rapidly in the fall, have the highest temperature during the summer months and lowest during the winter months. The data, as already stated, show most decidedly that the average temperatures of all the soils in the upper 6-inch layer are practically the same, varying, as a monthly average, only about 1° F. from May through summer and fall till freezing time, and this slight variation being in favor of the peat during July, August, and September. The variation is greater than 1° on certain individual days but this is largely due to rapid changes in the air temperature and to some other temporary factors. The 12 and 18-inch depths of all the soils have also practically the same temperature throughout the year except during thawing.

Theoretically, that is what should be expected if heat conductivity had no very marked influence, and if all the other conditions, evaporation, color and radiation, were about equal. The color was eliminated by covering all the soils by the same kind of soil; there was probably not a very great difference in evaporation. If these two factors were about equal for all soils then they all received about the same amount of warmth during the sun insolation. Their temperature, however, rose to different degrees on account of their different specific heats. The light soils having the smallest heat capacity under the field conditions attained the highest temperature during the day and the heavier soils the lowest. During the night they all cooled and since the previous study on radiation shows that all soils in well-moistened condition radiate equally well and since all these soils were covered with the same kind of soil and since it is conceived that radiation takes place at the surface, then all the soils lost about the same amount of heat, but received different degrees of lowering of temperature on account of

their different specific heats: the light soils with the smallest heat capacity cooled the most and the heavier soils with the largest capacity for heat the least. The average between the maximum and minimum temperature ought to give the same temperature for all the soils. That is just what has been obtained.

The temperature of the peat during the summer months is very interesting and deserves special attention. This material has not only the greatest water holding capacity of any other soil, but also the ability to absorb considerable moisture from the air, and on account of the slow but continuous evaporation of the water the temperature of this soil is kept low or much lower than that of other soils, as will be shown in a subsequent experiment, but when it is covered with a thin layer sand, as was done in the present experiment, its temperature is higher that that of the other different types of soil. A thin top dressing of sand, therefore, appears to increase the temperature of peat soils. This seems to be true also with the other heavy soils.

It would seem, then, from this study, that the greatest difference in temperature between the different types of soil exists in the early spring during thawing and immediately afterwards. Perhaps this is the most important period of the year from the practical or agricultural point of view, and especially where planting in the spring has to be done very early, because at this season small differences in the temperature will make great differences in the rate of germination of seed and in the rate of growth of plants. The differences in the present case are quite appreciable. As has already been mentioned, the gravelly and sandy soils not only thawed first followed by clay 1 day later, loam 2 days later, and peat 10 days later, but the temperature of the former soils rose immediately about 10° or more above that of the other soils. It took the clay soil 11 days to attain the same temperature as the light soils, the loam 12 days and the peat 32 days. Since this difference in the rate of thawing and rising of temperature in the various soil types is largely due to their different water content, and hence to the specific heat of water, the conclusion is irresistable that water is the most predominal controlling agent of soil temperature at this period and is of disadvantage. This disadvantage, however, becomes an advantage during the rapid fall of the air temperature in the cold parts of the year.

Special attention might also be called to the thawing of the 18-inch depth of peat 7 days before the 12-inch. This is interesting because it tends to confirm the general theory that the soil receives in the winter some heat from the interior of the earth.

EFFECT OF THE METEOROLOGICAL ELEMENTS ON THE SOIL TEMPERATURE.

So far the temperature of the different types of soil has been considered as affected or controlled by the difference of their intrinsic or soil factors. It will now be well to consider the temperature of these soils in relation to the external or meteorological elements which are air temperature, sunshine, wind pressure, precipitation, dew point, cloudiness, etc. These meteorological elements are very complex as to their behavior and make it very difficult to see the influence of all of

them on the soil temperature. In the first place, some of them run in a direct or parallel course with each other, while others run in an inverse course. This opposing or contrary action makes it very hard to notice or correlate the influence of any element on soil temperature unless it is very predominant. In the second place, all these elements do not obey the same law from day to day and hence this makes it still more difficult to trace their influence on the soil temperature.

As a rule, however, they tend to act with one another in the following manner: (1) the air temperature tends to vary inversely with the pressure; (2) the sunshine varies directly with the pressure; (3) the air temperature tends to vary directly with the sunshine in the summer; (4) the dew point varies directly with the air temperature; (5) the wind velocity may vary directly with either extreme of pressure; (6) the precipitation may be inversely proportional to the pressure.

Some of these meteorological factors tend to increase the soil temperature and others to decrease it. High air temperature would tend to raise the temperature of the soil while low barometric pressure would favor greater evaporation and consequently the soil temperature would be kept down, all other conditions being equal. Sunshine varying directly with the pressure would have a very positive influence in the warming of the soil. The wind velocity would have a cooling effect both on account of the continual movement of cool air and because of its accelerating effect upon evaporation. Precipitation in early spring may and may not raise the soil temperature, but in the summer it would tend to lower it both because its temperature is lower than that of the soil, and because of the greater evaporation that ensues immediately after a rainfall.

Space does not permit to discuss and to point out in detail the influence of these elements singly or in combination on the present soil temperatures study. The reader can get a fair idea of their general run and influence by an examination of the charts. It will suffice to say that the only factor which the soil temperature follows very closely and overwhelmingly is the air temperature and hence, also, the dew point. The relationship of the soil temperature to the other elements is not very regular simply because their influences are secondary to that of the air temperature, also on account of the fact that they vary so much from day to day, also because their influences are opposed, hence the effect of the one is offset by the effect of the other.

Special attention may be called to the effect of rainfall and snow on the soil temperature. It is the common belief that both these elements exert a large influence on soil temperature. It is claimed that in the spring the precipitation tends to raise the soil temperature very perceptibly and in the winter the snow acts as a blanket over the soil and prevents its rapid loss of heat and thereby keeps its temperature high.

Data collected on both these factors have led to the conclusion that the rainfall has been given more importance than it really deserves but that the snow does perform well the function that is attributed to it. As to the former, it will be seen by referring to the charts for April and May that whenever it rained the temperature of both the

air and the soil went down far below what it was before the rain began. This might have been an exceptional spring, but even then it does not appear that the rainfall could be very effective in raising the temperature of soil when it is considered (1) that it could be warmed up much faster on a rainless warm day, and (2) that the evaporation after the rainfall would tend to offset whatever warming effect the precipitation might have had.

From the theoretical standpoint snow ought to protect the soil from very severe freezing and thus keep its temperature higher and steadier. Its effect would seem to be analogous to that of a cover crop, cover of straw, etc. It ought to act as a blanket and reduce the rapid loss of heat, first by preventing the convection and wind current from coming in contact with soil, and second, because it is such a poor heat conductor. Where the thickness of the layer is considerable, snow is a very efficient agent in protecting the soil from very low temperature. An experiment that was conducted in the winter of 1912-1913 by placing two electrical resistance thermometers 6 inches into the ground, the area over one being kept free from snow and that over the other being kept covered with snow, shows a marked difference in temperature between the two cases. For instance, on March 5, when the minimum air temperature was—1° F., the temperature of the soil covered with about 5 inches of snow was 29.6° F., while that being free of snow was 23.6° F. On March 7, when the minimum air temperature registered—10° F., the temperature of the snow covered soil was 28.9° F., while that of the bare soil was 22.7° F. Before the snow had fallen, however, the temperature of both plots was the same and fluctuated to the same degree and with the same rapidity in both cases as the air temperature varied. The temperature records taken on the different types of soil and also on the soil with different amounts of organic matter throughout two winters show also very abundantly that whenever these soils were covered with a thick layer of snow their temperature remained much higher and steadier than when they were entirely unprotected, for the same or greater fall of air temperature. A typical example of this fact will be found in the months of February and March, 1913. During the first part of February, the soils were free of snow, and their temperature fell very low whenever the air temperature dropped down very low. On the 6th of that month, for instance, the minimum air temperature registered was 3° F., and the temperatures of some of the light soils went down as low as 12° F. On the 7th of March, however, the soils were covered with about 5 inches of snow. The minimum air temperature registered for this day was—10° F., while the temperature of all the soils remained along the freezing point, 32° F., showing very conclusively that snow tends to protect the soil from very rapid changes and low temperature, and it is therefore of great advantage in the winter time. This advantage, however, becomes a temporary disadvantage in the spring because a layer of snow will retard thawing on account of the large latent heat of fusion of snow.

This protecting effect of snow is undoubtedly greater on soils covered with straw or with growing vegetation which was planted in the fall than on bare soils, because the vegetation being very porous and com-

ing between the surface soil and the snow prevents a very intimate contact between the two and thereby cuts down the rapid loss of heat.

DAILY AND MONTHLY RANGE OF TEMPERATURE.

Mention has been made that the temperature of the different soil types under discussion, was recorded three times a day, at 7 a. m., 12 m., and 6 p. m. At these periods high and low temperatures were obtained at all three depths. These temperatures are probably not the absolute maximum and minimum. To obtain these it is necessary either to take records very often or continuously by means of thermographs or other continuous self recording instruments, because the absolute maximum and minimum temperatures of the various soils and of the different depths occur at different times. These low and high temperatures as obtained tri-urnally in the present work, however, are believed to be very close approximations to the absolute maximum and minimum, and especially for the upper 6-inch depth, which of course, for practical purposes, is the most important. The half-hour records which were taken at various times for the heat conductivity measurements, as well as the daily tri-urnal records, show that as a general rule the minimum occurred for the gravel and sand about 7 a. m., for the clay and loam about 12 m., and for the peat about 6 p. m. On the other hand the maximum was attained for the gravel and sand about 6 p. m., for the clay and loam a little later, and for the peat about 7 o'clock the following morning. The difference from the regular period to the time the highest or lowest reading was recorded is, therefore, not very large.

These high and low, or maximum and minimum, temperatures for all the different soils and for all three different depths are shown in the following tables and diagrams. The tables contain the daily and monthly high and low temperature for each soil and for each depth. On the diagrams are plotted the differences or amplitudes of these maxima and minima. The daily meteorological elements are also plotted and are the same as in the foregoing charts, except the air temperature, in which case the difference or amplitude is shown here instead of the average as in the preceding charts.

TABLE 30.—DAILY MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, DECEMBER, 1911.

Date—Maximum, minimum.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"
1 Max	32.	33.5	36.9	31.7	33 8	36.9	31.9	34.9	37.9	31.9	34.9	37.	32.1	34.5	37.9
Min	31 3	33.	35.9	31.	33.2	36.8	31 8	34 1	37 2	31 5	34 5	36 1	31.9	34 1	37.5
2 Max	32.	33.5	36.5	32.	34.1	37.4	32.	34.7	37.7	32.	35.	36.9	32.	34.5	37.5
Min...	31.5	33	36 1	31 7	33.5	36.9	31.9	34 3	36 8	31.9	34.	36.2	31.9	34	37 1
4 Max..	32.2	33.5	36.7	32.2	34.3	36.9	32.2	34.6	37.1	32.2	34.8	36.9	32.1	34.5	37.6
Min.	31 2	33 2	36 2	31.8	34	36 1	31.9	34 3	36.8	32	34 5	36 7	31 8	34.	37 3
5 Max.	32.5	34.5	36.5	32.	34.	37.	32.1	35.	37.	33.	35.	36.8	32.8	34.6	37.5
Min.	32 3	34	36 2	31 8	33 9	36 6	32.	34 8	36.9	32 2	34 8	36 7	32 2	34 2	37.
6 Max	32.4	33.9	36.5	32.1	34.	36.7	32.8	34.5	37.	32.6	34.6	36.5	32.1	34.5	37.2
Min.	32 2	33 7	36 2	31 9	33 8	36 5	32.1	34 3	36 8	31.9	34 2	36 3	32.	34 1	37.
7 Max	31.8	33.5	36.	31.7	34.	36.1	32.1	34.	36.8	32.1	34.1	36.3	32.1	34.1	37.2
Min..	31 7	33.1	35 7	31 2	32 7	35 8	31.5	33 9	36 3	31 9	33 8	35 6	31.5	33.6	36.8
8 Max	32.5	34.	36.2	33.4	34.2	36.8	32.7	34.8	37.2	33.	34.9	36.5	32.5	35.	37.2
Min	32 1	33 8	36	32 2	34	36 3	32 3	34 7	36.8	32 5	34 4	36	32	34.	36.9
9 Max	40.5	39.2	38.6	41.8	39.5	38.2	33.9	35.5	37.3	36.	36.5	37.4	32.8	34.9	37.
Min.	37.	36 9	37	37 5	37.	37.2	32 7	34 8	37.3	34 8	35 7	36.4	32 2	34 2	37.
11 Max	41.9	42.1	41.9	41.5	41.8	41.4	41.	40.	39.7	41.7	41.	40.2	32.5	34.2	37.2
Min.	41.8	42.	41	41.	41.5	40.5	40 2	39	38.	41 5	40.	39 5	32.	33 5	36.5
12 Max	38.2	40.4	41.5	37.5	39.4	41.2	39.	40.2	41.	39.5	41.	41.2	32.6	34.8	38.
Min	38	40.	40 8	37 2	38 9	40 8	38 9	40.1	40.	39.2	40 2	40 8	32 4	34 3	37.
13 Max.	37.	38.7	40.5	36.1	38.	40.6	37.8	39.5	40.8	37.3	40.	41.	33.2	35.4	38.2
Min	36 7	37 5	39 2	35	37 1	39 1	36.	38 8	40	36 2	38 2	39 8	32 1	35.	38.
14 Max.	34.9	36.4	39.1	34.	36.4	38.8	35.7	38.	39.	35.	37.9	39.3	33.	35.8	38.2
Min.	33.	34 9	37 4	32 2	34 5	37.8	33.3	36 8	38 2	33.1	35 4	38 2	32.	34.	38.
15 Max..	33.7	35.4	38.	33.3	35.1	38.1	34.5	37.1	39.1	34.1	36.6	38.5	32.9	35.	37.9
Min.	33.	35.	37.6	33.	34 5	37.7	33 9	36.4	38.7	33 9	36 5	38	32 3	34 6	37.8
16 Max	34.	35.7	38.	34.	35.6	38.3	34.2	36.8	39.	34.1	36.7	38.2	33.4	35.7	38.7
Min.	33 5	35.2	37 3	33 5	35.	37 8	33 6	36 5	38 9	33.9	36.6	38	33 1	35.4	38.5
18 Max	34.	35.9	37.9	34.2	36.	38.2	33.9	36.2	38.3	34.2	36.4	38.	33.5	36.1	38.4
Min.	33.9	35 1	37 7	33 8	35.2	37 8	33 7	36.	38 1	34 1	36.	37 8	33.	35.7	38.1
19 Max	35.2	36.4	38.1	34.9	36.2	38.8	35.	36.7	39.	34.9	36.8	38.2	34.2	36.4	39.
Min...	34 8	35 8	37.9	34 4	36.	38 1	34.1	36.5	38 8	34 7	36 8	38.	33 9	35 9	38.9
20 Max	34.8	36.8	38.	34.9	35.6	37.9	33.9	36.5	38.8	34.8	36.5	39.1	33.9	36.	39.
Min	33 1	34 5	36 8	33.	34 8	37.	33 1	35.5	37.6	33 2	35 6	37.	33	35.	37.8
21 Max	33.9	35.2	37.2	33.5	35.	37.	32.8	35.9	38.5	33.8	35.9	37.4	33.	35.1	38.2
Min...	32 5	33 8	35 8	32 1	33 9	36 5	32 2	34 4	36.6	32	34 6	36	31 8	34.	36.5
22 Max.	34.4	34.1	36.	35.	34.9	36.	32.2	34.5	36.5	33.5	34.8	36.1	31.9	33.9	36.9
Min..	32.	33 1	35 4	32 1	33 5	35 7	32.	33.4	36.	32 3	34	35 5	31 7	33.5	36.1
23 Max.	33.9	34.9	36.8	33.	34.5	36.5	32.5	34.5	36.1	33.2	35.	35.9	31.8	33.6	36.5
Min	33.	34 5	36	32 5	34 5	36.4	32 5	34 5	36.1	33 1	34 5	35 8	31 5	33 2	36.2
26 Max	32.5	33.9	35.9	32.5	34.1	36.5	31.9	34.7	36.1	32.5	34.1	36.	31.9	33.5	36.1
Min	31 9	33	35 3	31.	33 1	35 9	31 3	33 5	35.8	31 9	33 7	35 5	31 5	33 2	36.
27 Max	32.3	34.9	35.6	33.8	34.8	36.1	32.	34.7	36.5	33.3	34.7	35.6	32.8	34.	36.3
Min	31 4	32 8	33 8	31 6	33 3	35 1	31 3	32 4	35 5	31 8	32 7	34 4	31 2	32 9	34 5
28 Max	32.4	33.3	35.4	31.8	33.6	36.4	32.9	34.5	36.6	33.7	35.2	35.7	32 6	34.3	36.4
Min	31 6	32 2	34 9	30 5	32 9	35 6	32.	34 1	35 6	32 1	34 2	35 1	31 8	33 9	35 8
29 Max	31.3	32.4	35.	31.2	32.7	35.9	31.4	33.5	35.8	31.1	33.7	35.1	32.2	33.9	36.7
Min	29 7	30 8	33	28 9	31.9	35.	30 5	33 1	35 7	30 8	33 2	31 8	31 5	32.8	35.4
30 Max	30.6	31.8	33.8	30.5	31.6	34.4	30.7	32.9	35.	30.6	32.7	34.4	31.9	33.1	36.1
Min	29 7	29 9	33 1	30	31 3	34 2	29 9	32 3	34 4	30 1	32 2	34	30 5	32 6	34 8
Monthly range	1.31	0.92	0.64	1.09	0.75	0.60	0.66	0.62	0.60	0.69	0.72	0.64	0.60	0.61	0.60

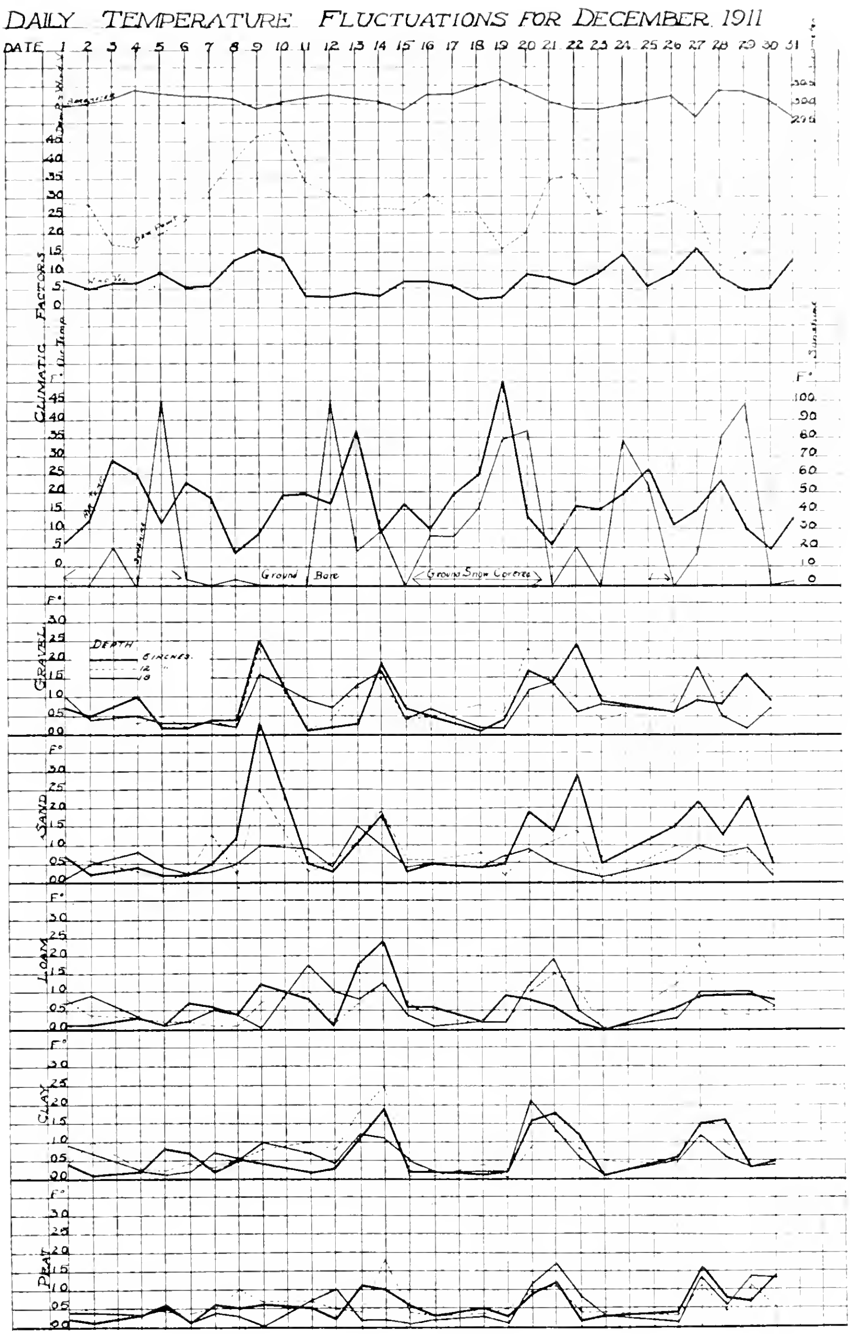
DAILY TEMPERATURE FLUCTUATIONS FOR DECEMBER 1911
DATE
CLIMATIC FACTORS
Dew Point
Wind Vel.
Air Temp
Sunshine
Ground Bare
Ground Snow Covered
GRAVEL
DEPTH
6 INCHES
12
18
SAND
LOAM
CLAY
PEAT

FIG. 16.

TABLE 31.—DAILY MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, JAN. 1912.

Date—Maximum, minimum.		Gravel. 6"	12"	18"	Sand. 6"	12"	18"	Loam. 6"	12"	18"	Clay. 6"	12"	18"	Peat. 6"	12"	18"
1	Max	30.7	31.9	35.	30.1	32.6	34.5	30.8	32.7	34.8	31.2	33.3	34.9	32.6	33.	35.4
	Min	27.8	29.	31.6	28.2	30.4	31.9	28.7	30.8	32.5	29.1	31.9	33.7	30.5	32.	34.9
2	Max	28.3	31.1	33.4	27.7	31.4	33.8	29.8	32.1	35.	30.4	32.2	33.5	30.	31.8	35.1
	Min	26.7	30.	32.3	25.6	29.6	32.7	28.3	30.6	33.2	28.1	30.7	31.	28.6	30.1	33.6
3	Max	24.4	28.6	32.1	22.	30.3	33.5	27.7	32.2	35.3	28.4	31.1	33.8	29.2	31.6	34.5
	Min	19.3	23.4	25.2	19.5	24.9	28.7	25.4	29.6	30.3	27.	30.6	32.1	28.5	30.9	33.6
4	Max	26.2	29.2	33.5	24.3	29.9	34.3	28.9	32.9	35.5	28.8	32.8	34.5	29.9	33.2	35.9
	Min	25.9	29.	33.1	24.	29.5	34.	28.8	32.8	35.2	28.5	32.5	34.5	29.8	33.	35.8
5	Max	21.4	26.8	33.1	19.5	27.8	33.5	26.5	32.6	35.	26.8	32.	34.1	27.	32.7	35.3
	Min	20.6	26.	32.3	17.	26.3	33.2	24.9	31.9	35.	24.9	31.8	33.8	24.4	32.4	35.2
6	Max	19.	24.9	32.2	15.3	25.7	33.1	23.5	31.9	34.9	23.8	31.8	34.1	21.5	32.2	35.5
	Min	18.9	23.7	31.	14.4	24.	32.1	23.	31.5	34.	23.3	31.2	33.5	21.	32.1	34.9
8	Max	21.2	24.	30.	18.	23.7	31.5	22.6	29.6	33.7	22.2	29.	33.2	20.5	31.9	34.1
	Min	18.9	22.8	29.5	15.	22.5	31.3	21.5	29.5	33.5	21.4	28.8	32.1	19.	31.5	34.
9	Max	25.	27.	30.4	22.1	25.8	31.6	25.	29.	32.8	24.2	28.2	32.	22.	31.	34.
	Min	23.7	25.8	30.1	20.	25.3	31.4	24.	28.7	32.5	23.1	27.4	31.5	21.5	31.	33.7
10	Max	25.6	27.6	30.8	23.2	27.	31.5	25.2	29.4	32.8	24.8	28.7	31.3	23.4	31.	34.
	Min	25.	27.3	30.5	23.1	26.8	31.	25.	29.	32.4	24.5	28.3	31.2	23.	30.6	33.5
11	Max	26.	27.9	30.4	23.9	28.	31.8	26.6	29.2	33.	24.9	28.1	31.6	24.	30.4	33.5
	Min	25.5	27.8	30.2	23.7	27.2	31.	25.8	29.	32.3	24.4	28.	31.	23.9	30.	33.4
12	Max	26.3	27.9	30.3	24.8	28.2	31.1	26.1	29.2	31.4	24.9	28.1	30.9	23.6	29.	33.
	Min	25.8	27.	30.	23.1	27.	30.1	25.1	29.	31.1	24.	27.5	30.6	22.8	28.8	32.8
13	Max	24.6	27.	30.1	23.4	27.5	30.3	25.2	28.2	31.3	22.3	27.5	30.5	22.	28.2	32.4
	Min	24.3	26.2	29.	23.	26.9	30.2	24.8	28.1	31.1	22.2	26.8	30.4	21.7	27.2	32.
15	Max	25.6	27.9	30.8	24.8	27.9	30.8	25.6	28.7	31.8	24.4	27.7	30.7	24.4	28.6	32.7
	Min	25.2	27.9	30.5	24.5	27.6	30.5	25.3	28.5	31.4	24.1	27.4	30.2	24.1	28.4	32.4
16	Max	25.4	27.6	30.3	24.	27.7	30.5	25.5	28.8	31.5	24.5	27.3	30.	23.5	28.4	32.4
	Min	25.	27.5	30.3	23.9	27.7	30.5	25.3	28.7	31.4	24.3	27.2	30.	23.2	28.	32.3
17	Max	25.	27.3	30.2	24.8	27.5	30.4	25.5	28.8	31.3	25.	27.3	30.2	23.7	28.1	32.3
	Min	24.4	26.	29.	23.2	26.2	29.5	25.1	28.6	30.9	24.5	27.	29.9	23.2	27.9	32.1
18	Max	29.	30.	31.	27.7	29.	31.4	27.3	29.1	31.9	27.	28.5	30.6	26.8	28.8	32.8
	Min	27.	28.3	30.8	25.	28.5	31.2	26.5	28.9	31.5	26.	27.7	30.3	25.7	28.6	32.5
19	Max	29.5	30.	31.	28.3	29.9	31.5	27.5	29.3	31.9	27.6	28.8	30.5	27.1	28.8	32.8
	Min	29.	29.7	30.9	27.9	29.8	31.1	27.3	29.1	31.4	27.3	28.6	30.4	26.6	28.7	32.6
20	Max	27.6	28.7	30.8	26.3	29.	31.3	27.	28.9	31.2	27.	29.6	30.3	25.5	28.6	32.
	Min	27.	27.5	30.	25.	28.6	29.9	25.7	28.4	30.	26.	27.9	29.6	23.	27.7	31.3
22	Max	28.2	28.3	30.8	27.	29.1	30.8	26.2	29.1	31.	27.2	29.2	30.3	26.3	28.4	32.
	Min	27.	27.8	29.9	25.5	28.3	30.	26.	28.3	30.1	26.9	28.1	29.2	25.3	27.1	31.6
23	Max	28.4	29.3	30.9	27.7	29.5	30.9	27.1	29.1	31.1	28.	29.1	30.3	26.8	28.5	32.
	Min	27.8	28.8	30.	27.	28.5	30.4	26.5	28.5	30.6	27.8	29.	30.	26.5	28.5	31.8
24	Max	29.1	30.	31.4	28.4	30.2	31.8	28.4	30.	31.7	28.7	30.	31.1	27.4	29.2	32.3
	Min	28.4	29.8	31.3	28.	30.	31.5	28.	29.9	31.3	28.4	29.8	30.5	27.2	29.	32.
25	Max	29.	30.	31.7	28.	30.1	31.7	28.2	30.	31.8	28.5	29.7	31.2	27.2	29.1	32.3
	Min	28.7	29.7	31.5	27.7	29.9	31.5	28.	29.9	31.4	28.2	29.7	30.9	26.9	29.	32.
26	Max	28.6	29.6	31.5	27.5	30.	31.5	28.1	30.	31.6	28.3	30.	31.2	27.2	29.5	32.4
	Min	28.5	29.4	31.	27.3	29.9	31.3	28.	29.9	31.5	28.1	29.9	30.9	27.	29.	32.2
27	Max	29	30.	31.3	27.7	30.2	31.6	28.2	30.	31.5	28.6	30.	31.	27.4	29.5	32.1
	Min	28.8	29.8	31.	27.5	30	31.6	28	29.8	31.3	28.4	29.8	30.6	26.9	29.1	31.8
29	Max	28.5	29.4	31.1	27.6	29.8	31.2	27.9	29.4	31.2	28.4	29.8	30.7	27.	28.8	31.8
	Min	27.9	28.7	30.	26.8	28.3	30.7	27.3	28.7	30.5	27.8	28.8	29.9	26.6	28.4	31.
30	Max	28.2	29.2	30.2	27.2	28.9	31.	27.5	28.9	30.9	28.2	29.1	30.2	26.9	28.5	31.4
	Min	27.7	28.9	29.4	26.5	27.6	30.1	26.9	28.1	29.5	27.2	28.4	29.5	26.2	27.8	30.1
31	Max	29.2	29.9	31.	28.2	29.4	31.	28.	29.1	30.9	28.8	29.1	30.1	27.8	29.	31.
	Min	28.8	29.5	30.3	27.6	29.	30.9	27.9	28.9	30.8	28.5	29.	30.	27.4	28.8	30.8
Monthly range		0.94	0.89	0.92	1.10	0.95	0.72	0.70	0.50	0.75	0.70	0.52	0.58	0.76	0.45	0.41

DAILY TEMPERATURE FLUCTUATIONS FOR JANUARY 1912

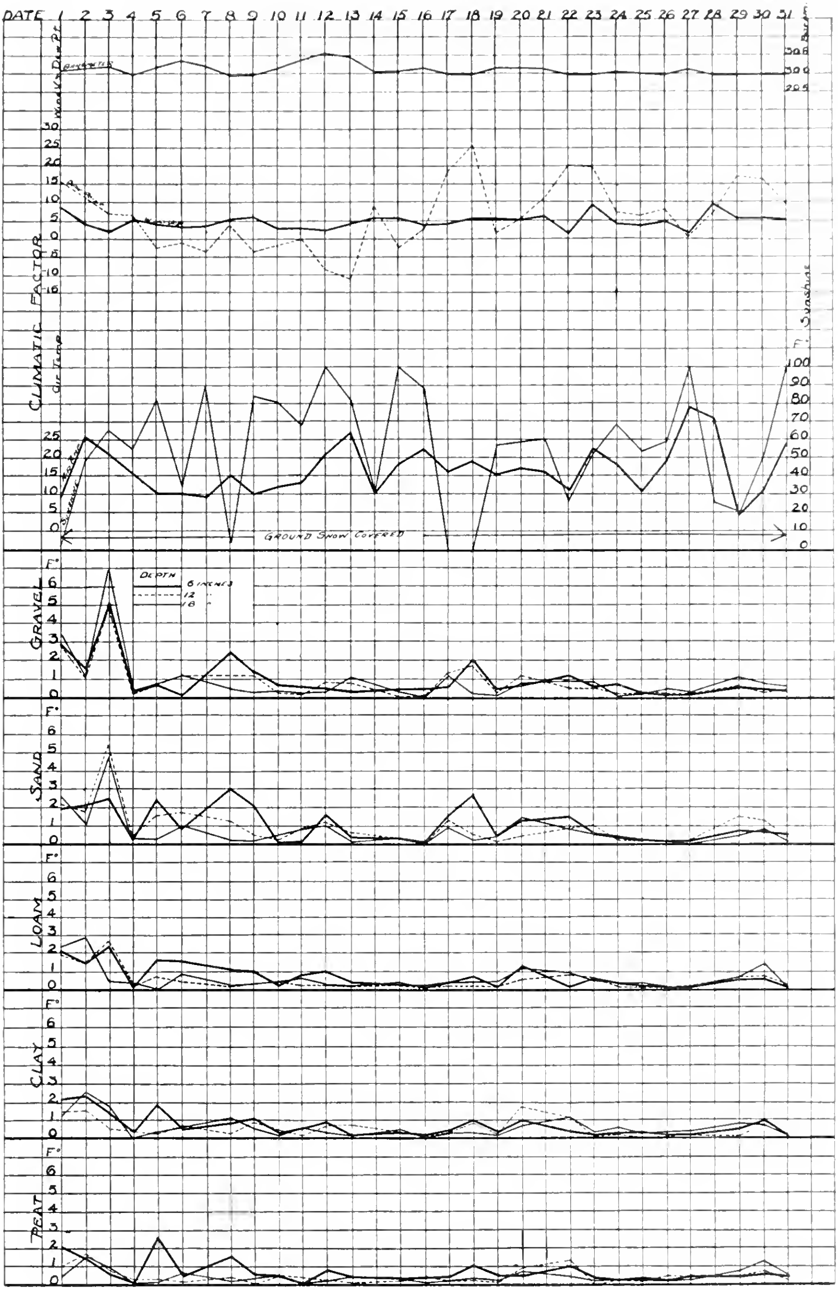

FIG. 17.

TABLE 52.—DAILY MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, FEBRUARY, 1912.

Date	Maximum, minimum.	Gravel. 6"	Gravel. 12"	Gravel. 18"	Sand. 6"	Sand. 12"	Sand. 18"	Loam. 6"	Loam. 12"	Loam. 18"	Clay. 6"	Clay. 12"	Clay. 18"	Peat. 6"	Peat. 12"	Peat. 18"
1	Max	29.	29.9	31.	27.7	29.5	31.2	28.7	29.2	31.	28.6	29.3	30.4	27.5	28.9	31.2
	Min	28.8	29.7	30.6	27.2	29.4	30.9	27.6	28.9	30.8	28.2	29.1	30.2	27.	28.6	31.
2	Max	28.9	30.	31.3	27.8	29.7	31.1	28.5	29.2	31.	28.8	29.5	30.5	27.5	28.8	31.4
	Min	28.8	29.8	30.8	27.3	29.4	30.9	27.8	28.9	30.8	28.	29.	30.	26.8	28.2	31.
3	Max	29.	30.	31.2	27.6	29.6	31.	28.5	29.3	31.	28.8	29.8	30.7	27.4	29.3	31.5
	Min	28.4	29.5	30.6	27.	29.	30.5	28	28.8	30.3	28.4	29.4	30.4	27.	28.8	30.8
5	Max	28.6	30.	31.6	27.5	30.	31.4	28.1	30.1	31.3	28.5	30.1	31.	27.5	29.	31.5
	Min	28.4	29.6	30.6	27.3	29.5	30.8	28.	29.9	30.5	28	29.8	30.2	27.1	28.	30.4
6	Max	28.5	29.8	31.7	27.5	30.	31.4	28.1	30.	31.6	28.7	30.4	31.1	27.	29.2	32.
	Min	28.1	29.7	31.3	27.	29.8	31.3	27.9	29.8	31.5	28.6	30.3	31.	26.9	29.1	31.8
7	Max	28.5	30.	31.1	27.2	29.9	31.3	28.2	29.6	31.6	28.6	30.2	31.	27.1	29.	31.9
	Min	28.4	29.9	31.	26.9	29.7	31.1	28	29.6	31.2	28.5	29.9	30.8	26.9	28.9	31.9
8	Max	28.4	29.4	30.6	27.2	29.9	31.2	27.6	29.1	30.9	28.1	29.7	30.4	27.1	29.	31.7
	Min	28.1	29.2	30.5	26.8	29.7	31.	27.5	28.9	30.7	27.8	29.4	30.2	26.8	28.8	31.3
9	Max	28.7	29.8	31.2	26.9	30.	31.7	28.1	30.3	31.5	28.6	29.6	30.6	27.3	29.3	32.1
	Min	28.4	29.2	30.9	26.3	29.5	31.4	27.6	29.5	31.	28.3	29.4	30.3	27.2	29.1	31.9
10	Max	28.4	29.	31.	25.5	29.	31.4	27.2	29.7	30.9	27.1	29.3	30.5	27.	28.8	31.3
	Min	26.8	28.9	30.9	22	28.	31.	25.5	29.4	30.8	26.	28.9	30.2	26.6	28.7	31.
12	Max	28.1	29.1	31.	25.2	28.3	31.3	26.3	29.3	30.9	26.4	29.	30.2	26.7	28.9	31.7
	Min	27.9	29.	30.9	25.	28.1	30.4	26.1	29.	30.9	26.2	28.8	30.1	26.2	28.4	31.5
13	Max	27.9	29.	30.6	25.3	28.2	30.7	26.8	28.7	30.6	26.2	28.4	29.9	26.8	28.6	31.2
	Min	27.5	28.9	30.6	25.2	27.9	30.3	26.5	28.4	30.3	25.9	28.3	29.9	26.7	28.5	31.2
14	Max	28.3	29.	30.7	25.9	28.7	30.3	26.3	28.5	30.8	26.4	28.5	30.	27.	28.5	31.6
	Min	27.9	28.9	30.5	25.3	28.4	30.3	26.1	28.3	30.6	26.3	28.3	30.	27.	28.3	31.3
15	Max	28.8	29.6	30.7	27.4	29.1	30.6	27.	28.8	31.	27.	28.7	30.2	27.6	28.7	31.6
	Min	28.8	29.3	30.5	26.3	29.	30.3	26.9	28.4	30.8	27.	28.7	29.9	27.3	28.5	31
16	Max	29.	29.5	30.4	28.2	29.4	30.7	27.4	28.5	30.5	27.6	28.9	30.1	28.1	28.9	31.2
	Min	28.9	29.5	30.2	27.9	29.2	30	27.1	28.3	30.	27.3	28.8	29.1	27.6	28.7	31.
17	Max	28.8	29.3	30.2	28.2	29.5	30.4	27.4	28.3	29.7	27.6	28.6	29.5	28.3	29.	31.1
	Min	28.3	28.8	29.9	27.9	28.6	30.	27.3	28.1	29.5	27.1	28.5	29.2	28.2	28.9	30.8
19	Max	30.5	31.	31.7	31.	31.	31.7	29.3	30.1	30.4	29.2	29.4	30.3	29.8	30.1	31.1
	Min	28.8	29.3	30.2	29.2	29.7	30.8	28.2	29.	30	27.8	28.	29.9	28.9	29.4	31.
20	Max	30.7	31.1	31.5	31.	31.2	31.6	29.5	30.2	31.1	29.9	30.	30.8	30.3	30.2	31.3
	Min	30	30.5	31.2	30.8	31.	30.9	29	29.5	30.5	29.4	29.5	30.7	29.6	29.8	31.
23	Max	29.5	30.	30.8	30.2	30.4	31.2	29.2	29.6	30.6	28.9	30.1	30.4	29.1	30.3	31.5
	Min	29.4	29.9	30.5	30.2	30.3	30.7	28.5	29.5	30.3	28.8	29.5	30.4	28.	29.2	31.3
24	Max	30.4	31.5	31.2	31.7	31.4	31.1	30.1	30.4	31.3	30.6	30.7	31.	29.5	30.5	30.8
	Min	30.1	30.4	30.4	30.6	30.3	30.5	29.8	30.2	30	29.4	29.5	30.2	29.4	29.5	30.6
26	Max	31.6	31.5	31.6	31.5	31.7	31.9	29.7	30.6	31.4	30.6	31.4	31.	30.8	30.3	31.9
	Min	30.3	30.5	30.6	30.5	30.5	31.	29.	29.7	30.3	29.3	29.6	30.2	29.4	29.4	30.2
27	Max	30.6	31.2	31.7	31.2	31.9	32.	30.1	30.6	31.4	30.3	31.	31.2	30.9	30.9	31.9
	Min	30.4	31.	30.9	30.8	31	31	29.4	30.	31.	30.	30.2	30.7	30	30	31.5
28	Max	31.	31.3	31.3	31.2	31.4	31.8	29.8	30.2	31.2	30.2	30.6	30.9	30.3	30.4	31.5
	Min	30.9	31.1	31.1	31.	30.9	31.3	29.8	30.1	30.9	30.1	30.3	30.9	30.3	30.2	31.4
29	Max	31.1	31.4	31.5	31.	31.3	31.6	30.1	30.7	31.4	30.8	30.8	31.3	30.8	30.5	31.5
	Min	31	31.1	31.4	31.	31.2	31.5	29.9	30.3	31.	30.3	30.6	31.2	30.5	30.4	31.3
Monthly range		0.42	0.37	0.41	0.63	0.48	0.46	0.46	0.37	0.42	0.47	0.44	0.32	0.43	0.39	0.36

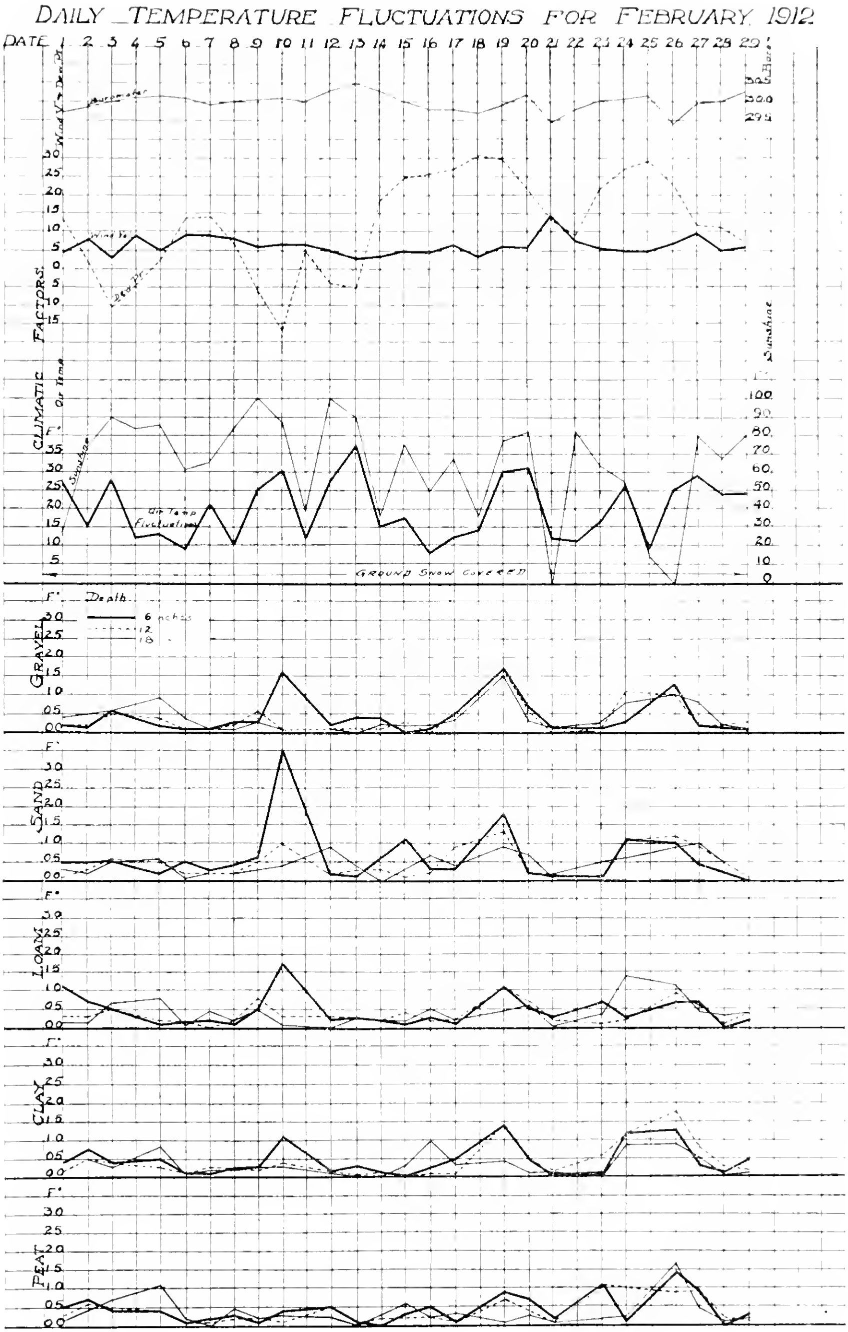
DAILY TEMPERATURE FLUCTUATIONS FOR FEBRUARY 1912
DATE 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Barometer
Wind V. + Dew Pt.
Wind Ve.
Dew Pt.
CLIMATIC FACTORS
Air Temp.
Sunshine
Air Temp Fluctuations
GROUND SNOW COVERED
Depth
6 inches
12
18
GRAVEL
SAND
LOAM
CLAY
PEAT

FIG. 18.

TABLE 33. DAILY MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, MARCH, 1912.

Date	Maximum, minimum.	Gravel. 6"	Gravel. 12"	Gravel. 18"	Sand. 6"	Sand. 12"	Sand. 18"	Loam. 6"	Loam. 12"	Loam. 18"	Clay. 6"	Clay. 12"	Clay. 18"	Peat. 6"	Peat. 12"	Peat. 18"
1	Max	31.1	31.3	31.6	31.1	31.4	31.7	30.	30.5	31.2	30.8	30.6	31.3	30.5	30.7	31.4
	Min	30.9	31.1	31.5	31.1	31.1	31.7	29.9	30.4	31.	30.5	30.5	31.3	30.5	30.6	31.4
2	Max	31.	31.3	31.4	31.	31.5	31.9	30.	30.5	31.4	30.5	31.	31.8	30.4	30.9	31.8
	Min	30.9	31.2	31.3	31.	31.4	31.8	29.9	30.5	31.2	30.4	30.9	31.3	30.3	30.7	31.7
4	Max	30.9	31.2	31.6	31.	31.3	32.	30.	31.	31.4	30.7	31.2	31.9	29.9	30.7	31.8
	Min	30.8	30.9	31.3	30.8	30.9	31.7	29.6	30.8	31.4	30.3	30.9	31.3	29.8	30.1	31.5
5	Max	30.	30.8	31.5	30.7	31.1	31.9	29.8	30.9	31.5	30.	30.9	31.3	29.8	30.5	31.4
	Min	29.9	30.4	31.2	30.	31.1	31.9	29.1	30.8	30.9	29.4	30.9	31.	28.8	30.	31.3
6	Max	29.9	30.3	31.2	29.9	31.1	31.8	29.	30.	31.	29.1	30.	30.8	29.	30.	31.5
	Min	28.6	30.	31.1	29.2	30.9	31.5	28.5	29.9	30.3	29.1	30	30.8	28.4	29.3	31.
7	Max	29.2	30.3	31.8	30.	31.2	32.1	29.2	30.5	31.8	30.	30.8	31.4	28.9	30.	31.6
	Min	28.9	29.9	31.4	29.3	30.9	32.1	28.9	30.	31.	29.5	30.3	31.	27.3	29.7	31.1
8	Max	29.1	30.	31.1	29.5	30.8	31.9	28.8	29.9	30.9	30.	30.1	30.9	28.6	29.9	31.3
	Min	28.9	29.5	30.8	29.2	30.	31.	28.3	28.9	30.	28.3	29.3	30.3	28.5	29.	30.9
9	Max	29.9	30.4	31.1	30.1	30.9	31.5	29.2	30.	30.9	29.4	30.	30.3	29.2	29.4	31.2
	Min	29.8	30.3	31.1	30.	30.6	31.2	29.1	30.	30.6	29.	29.8	30.2	28.5	29.	31.2
11	Max	30.5	31.2	31.8	30.9	31.6	32.	29.6	30.5	31.4	30.	31.	31.5	30.	30.	31.7
	Min	29.7	30.2	31.3	29.4	30.8	31.6	28.9	29.9	30.8	29.9	30.3	30.9	29.3	29.7	31.2
12	Max	29.8	30.2	31.1	29.9	30.8	31.4	29.4	30.1	30.8	30.	30.3	30.9	29.4	30.	31.
	Min	29.4	30.	31.	29.3	30.7	31.2	29.1	29.9	30.3	29.3	29.9	30.4	29.2	29.8	30.9
13	Max	30.5	30.9	31.9	30.6	31.	31.6	29.9	30.5	31.1	30.1	30.5	31.4	29.8	30.3	31.6
	Min	30.	30.5	31.3	30.	30.8	31.4	29.4	30.	30.7	29.9	30.1	30.9	29.6	30.	31.1
14	Max	29.9	30.1	31.	29.6	30.4	31.3	29.3	30.	30.9	29.8	30.	30.6	29.4	29.9	30.9
	Min	29.3	29.6	30.1	29.1	30.	30.9	28.8	29.3	30.1	28.9	29.5	30.	28.3	28.5	29.9
15	Max	30.2	30.4	31.2	30.	30.3	31.2	30.	30.5	31.4	29.9	30.4	31.3	29.8	30.3	31.
	Min	30.2	30.4	31.2	30.	30.3	31.2	30.	30.5	31.4	29.9	30.4	31.3	29.8	30.3	31.
16	Max	30.5	30.9	31.5	30.	30.5	31.6	30.	30.3	30.9	30.3	31.	31.3	29.9	30.4	31.3
	Min	29.5	29.9	30.6	29.7	30.	31.1	29.	29.6	30.3	29.9	30.	30.4	29.4	29.5	30.4
18	Max	30.3	30.6	31.	30.3	30.7	31.4	29.5	30.2	31.	30.	30.2	31.	29.9	30.	31.1
	Min	30.1	30.4	30.9	30.1	30.5	31.2	29.4	30.	30.8	29.9	30.1	30.8	29.8	29.9	30.9
19	Max	30.7	30.9	31.2	30.8	31.	31.7	29.8	30.2	31.	30.2	30.5	30.8	30.1	30.1	31.2
	Min	30.1	30.5	30.9	30.3	30.7	31.3	29.5	29.9	30.7	29.9	30.2	30.5	29.9	29.9	31.
21	Max	28.9	29.4	30.3	29.8	30.3	30.9	28.6	29.5	30.	29.	29.6	29.9	28.8	29.9	30.8
	Min	28.3	29	29.9	29.	29.1	29.9	27.9	28.3	28.6	28.9	29.1	29.4	28.6	29.	30
22	Max	29.4	29.8	30.6	30.2	31.2	31.	29.2	30.1	29.9	29.5	30.1	30.6	30.	30.	30.3
	Min	27.8	28.8	30.	29.	29.7	29.9	28.1	28.9	29.1	29	29.6	29.	28.8	29.6	30
23	Max	29.5	30.2	30.6	30.	30.6	31.5	30.	30.3	30.1	30.2	30.7	30.6	30.7	29.9	31.3
	Min	29.2	29.9	30	29.9	29.9	31.	29.7	29.3	29.3	29.8	30.2	29.8	29.5	29.5	31.
25	Max	30.	30.4	31.4	30.3	31.3	31.8	29.9	30.6	31.5	30.1	30.6	31.4	30.	30.2	31.7
	Min	29.4	30.1	31.3	30.3	31.1	31.1	29.5	30.	30.9	29.8	30.2	30.6	29.8	29.5	31.2
26	Max	30.5	31.2	31.5	30.8	31.3	31.7	29.7	30.7	30.6	30.	30.5	30.7	30.	30.3	31.3
	Min	30.2	30.8	31.2	30.6	29.9	31.5	29.3	30.	30.2	29.8	29.9	30.2	29.8	30.	31.
27	Max	30.5	30.9	31.3	30.8	31.1	32.1	31.3	30.6	31.5	30.7	30.9	31.2	30.1	30.5	31.7
	Min	29.7	30.4	30.8	29.3	30.2	31.	29.4	30.3	30.8	30.5	30.5	30.9	29.9	30.4	31.3
28	Max	30.8	31.2	31.2	30.8	31.2	32.	30.4	31.	31.	30.7	30.8	31.	29.9	30.8	31.9
	Min	30.	30.6	30.3	30.	30.4	31.	29.4	30.	30.3	30.3	30.3	30.7	29.8	30.4	31.2
29	Max	31.8	31.6	31.4	31.2	31.3	31.8	30.8	31.2	31.3	30.7	31.7	32.	30.7	30.3	31.1
	Min	28.8	28.2	29.	28.3	29.	29.1	28.5	28.8	29.5	29.5	30	30.1	29.6	29.8	30.7
30	Max	30.4	30.9	30.9	30.9	30.9	32.1	30.7	30.6	30.9	30.8	31.1	31.	30.8	30.8	31.9
	Min	30.2	30.6	30.8	30.8	30.7	31.8	30.2	29.9	30.7	29.6	30.7	31.	30.7	30.3	30.1
Monthly range		0.58	0.53	0.44	0.57	0.57	0.51	0.59	0.57	0.58	0.43	0.43	0.84	0.47	0.46	0.43

DAILY TEMPERATURE FLUCTUATIONS FOR MARCH, 1912.

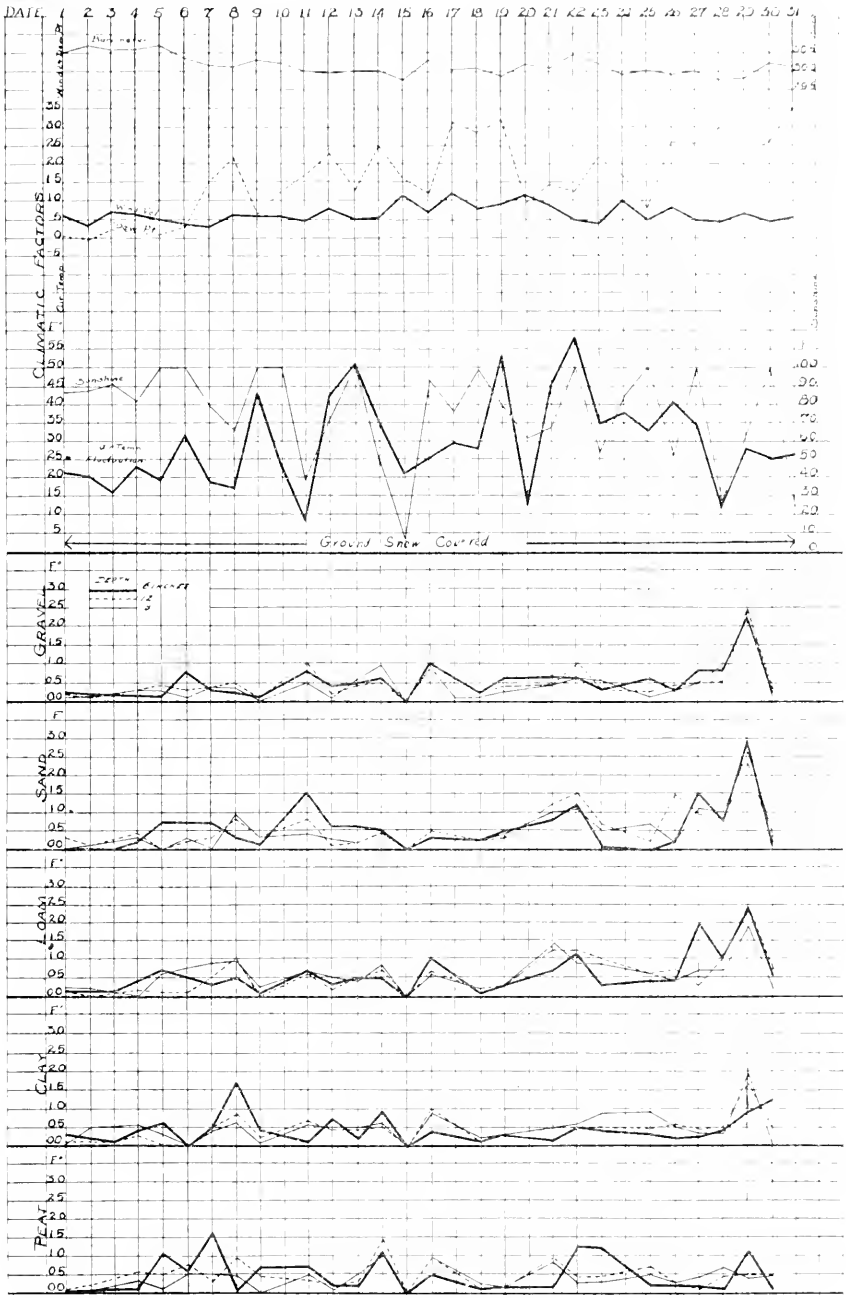

FIG. 19.

TABLE [illegible]. DAILY MAXIMUM AND MINIMUM TEMPERATURES OF DIFFERENT TYPES OF SOIL, APRIL, 1912.

Day of Month		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	Max	32.1	31.9	31.7	31.5	31.9	31.9	31.2	31.5	31.9	32.	31.7	31.8	31.5	31.6	31.9
	Min	31.7	31.7	31.4	31.2	31.8	31.7	30.9	31.4	31.7	31.1	31.4	31.6	31.4	31.2	31.6
2	Max	31.	31.2	31.2	31.3	31.3	31.3	31.	31.2	31.2	31.	31.4	31.3	31.1	31.1	31.3
	Min	30.9	30.8	30.8	30.9	30.9	30.9	30.	30.3	30.8	30.8	30.7	30.5	30.5	30.	30.6
3	Max	30.6	30.9	30.6	30.5	30.8	31.	31.	31.	31.2	31.	31.1	31.1	30.8	30.3	31.
	Min	29.2	29.5	29.	29.4	29.3	30.1	29.8	30.8	31.	30.8	30.9	31.	30.8	29.4	30.4
4	Max	32.	31.1	30.9	30.9	31.	31.3	30.9	30.8	31.	30.8	30.8	30.9	30.5	30.	30.5
	Min	30.8	30.	30.	29.9	30.1	30.9	29.	29.2	29.9	30.4	30.	30.	29.4	29.1	29.4
5	Max	39.6	34.1	31.3	36.6	31.	31.4	30.2	30.6	31.	33.9	31.	31.1	30.7	30.4	31.1
	Min	32.5	31.1	31.4	30.9	30.9	31.4	30.2	30.3	30.9	30.	30.8	30.7	30.4	29.9	31.
6	Max	44.5	40.	32.8	43.9	36.8	32.3	31.9	30.4	31.	38.2	31.	31.	30.5	30.1	31.2
	Min	37.5	34.5	31.2	34.8	31.4	31.4	30.1	30.4	30.8	33.9	30.8	30.8	30.3	29.9	31.
7	Max	41.7	41.	37.1	37.9	37.	34.8	32.7	30.3	31.	37.5	31.	31.	30.6	30.2	31.
	Min	38.8	38.9	36.9	36.1	35.6	34.5	32.2	30.1	30.8	35.2	30.6	30.5	30.3	30.	30.9
8	Max	40.	37.3	35.	33.7	36.1	34.1	33.1	30.6	31.	35.8	31.1	31.	30.8	30.5	31.2
	Min	33.5	34.7	35.	32.2	33.1	33.5	31.	30.2	30.9	31.9	30.7	30.5	30.5	30.1	31.1
9	Max	44.8	40.8	36.5	45.7	40.	35.8	36.	30.4	31.1	39.5	31.3	30.9	30.6	30.5	31.1
	Min	37.	37.2	35.6	36.	36.	34.9	33.	30.3	30.9	35.	31.	30.9	30.6	30.4	31.
10	Max	47.	42.8	38.1	48.	42.8	38.	37.8	30.6	31.1	41.	33.	31.1	30.8	30.4	31.2
	Min	38.6	39.2	37.6	38	38.3	37.	33.8	30.3	30.7	36.6	32.	30.9	30.4	30.3	31.
11	Max	50.5	45.	39.5	50.5	44.1	39.	39.8	30.8	31.	43.9	34.5	30.9	30.9	30.2	31.1
	Min	41.	41.	38.5	49.2	39.9	38.	35.1	30.3	30.9	37.1	33.3	30.8	30.5	30.1	31.
12	Max	49.	45.4	41.5	48.5	44.5	40.1	40.	31.7	31.	44.8	38.5	35.2	30.7	30.2	31.
	Min	45.	43.9	41.	44	42.8	39.9	38.4	31.2	30.9	42.	37.	33.	30.5	30.1	30.8
13	Max	47.	44.8	41.6	46.6	43.9	41.	39.4	33.	31.2	44.5	40.	38.1	30.9	30.2	31.
	Min	41	43.6	41.5	43.1	42.5	40.4	38.	32.9	31.	42.4	39.8	37.1	30.5	30.1	30.9
15	Max	51.5	49.	44.	52.	47.3	43.	45.7	39.8	37.1	49.5	44.	41.3	34.3	31.	31.5
	Min	42	42.	39.2	40.8	40.3	38.1	37.9	34.	33.	41.4	38.3	36.4	31.8	30.	31.
16	Max	48.	46.8	44.3	48.1	46.	43.8	45.2	42.2	39.	47.7	44.2	42.2	34.	30.9	31.6
	Min	45.5	44.8	42.5	44.5	43.2	42.	42.9	41.1	38.2	45.	43	41	33.	30.	30.6
17	Max	44.5	43.8	43.5	44.	43.2	42.8	42.9	42.4	40.5	44.3	43.8	42.2	34.1	30.3	31.4
	Min	42.5	43.1	42.8	41.5	42.	42.	42.2	42.	40.1	43.5	42.8	41.9	33.9	30.2	31.4
18	Max	41.5	41.8	42.2	41.	40.8	41	40.7	41.5	40.6	41.3	42.4	41.5	33.6	30.6	31.6
	Min	40.4	41.2	41.8	39.4	40.	40.2	40.2	41.1	40.2	41	41.4	41.4	33.5	30.5	31.5
19	Max	45.	43.1	40.9	45.2	43.	42.0	42.3	40.	40.	44.5	40.	40.1	33.6	30.5	31.8
	Min	37.4	39.4	40	36.5	38.5	39.9	38.4	40.	39.8	38.5	39.9	40.4	32.8	30.2	31.6
20	Max	39.8	40.7	42.	40.3	39.9	41.5	44.	41.	42.	41.	43.1	40.4	36.	30.6	32.4
	Min	38.1	36.7	38	38.7	38.9	39.	38.4	38.2	38	38	37.4	37.5	32.	29.6	31.
22	Max	48.2	47.1	44.4	47.7	46.9	44.4	47.8	44.8	41.8	48.2	44.6	43.5	39.4	30.6	31.9
	Min	46	46	44.3	45.3	45.5	44.	46.9	44.6	41.8	46.9	44.6	43.2	38.9	30.6	31.8
23	Max	47.2	44.8	43.1	49.	44.9	43.8	44.4	43.9	42.7	45.1	43.5	43.	36.6	30.7	32.
	Min	39.8	41.3	42.1	39.4	40.6	41.9	41.2	42.2	41.3	41.3	42.2	41.5	35.5	30.3	31.8
24	Max	51.7	47.9	43.6	52.1	47.5	43.5	48.1	43.8	41.9	49	44.	42.5	39.	30.5	32.
	Min	41.5	44.9	43.1	41.8	41.3	42.8	45	43.5	41.6	44.9	43.1	42.2	38.	30.3	32.
	Max	52.	48.4	44.4	53.	47.6	44.2	49.	44.9	42.5	49.6	44.8	43.3	39.2	30.8	32.1
	Min	45.4	44.7	43.8	42.5	43.7	43.1	45.3	44	42.4	44.9	44.5	43.1	38.3	30.2	32.
	Max	53.7	49.9	46.9	54.3	49.5	45.5	50.8	47.2	44.2	51.8	46.5	45.5	42.	31.	33.1
	Min	[illegible]	47.6	45	48.9	46.5	44.8	48.6	46.1	43.3	48.7	46.	44.4	41.3	30.5	32.2
	Max	54.8	51.	46.6	55.2	50.3	46.7	52.1	47.9	45.	55.5	47.8	45.9	43.8	31.	33.1
	Min	[illegible]	[illegible]	[illegible]	48	48	46.5	49.2	47.6	44.2	49.4	47.2	45.3	42.8	30.9	32.9
29	Max	44.	43.8	44.5	43.6	43.5	44.5	44.8	46.	45.	44.	45.2	45.1	40.7	31.5	34.1
	Min	42	[illegible]	[illegible]	42	43	43.2	44	44.5	44.2	43.5	41.	41	39.9	31.4	34.
30	Max	50.1	46.5	43.	52.6	46.8	43.	46.	44.	43.6	47.6	43.3	43.9	39.5	31.5	34.9
	Min	[illegible]	41	[illegible]	[illegible]	41	42.3	41.5	43	43	41.	42.8	43	38	31.4	34.1
Monthly range		4.93	2.66	0.96	5.44	2.59	0.93	2.47	0.84	0.68	3.25	1.23	0.85	0.76	0.39	0.18

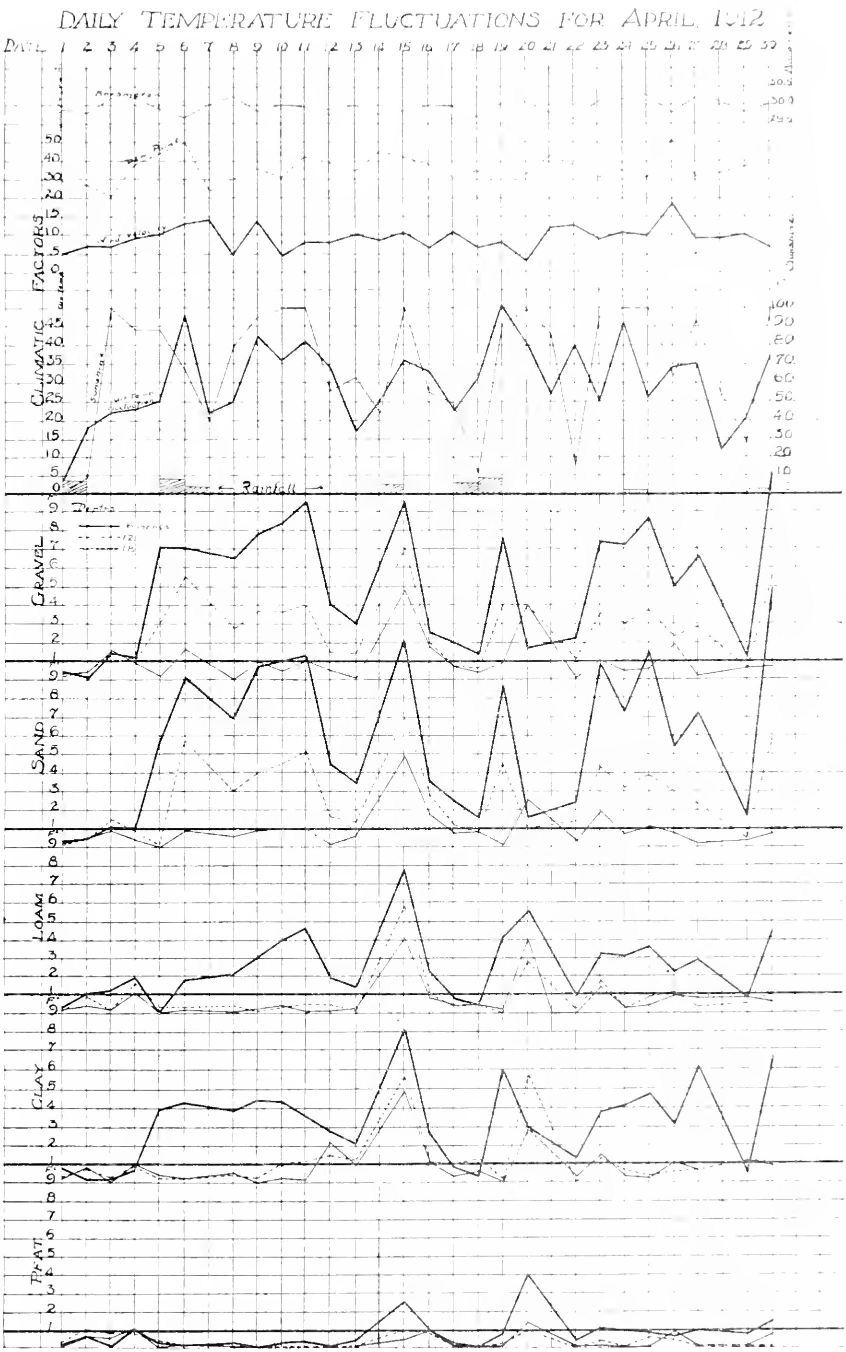
DAILY TEMPERATURE FLUCTUATIONS FOR APRIL, 1912
DATE
CLIMATIC FACTORS
Rainfall
GRAVEL
SAND
LOAM
CLAY
PEAT

FIG. 20.

TABLE 55.—DAILY MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, MAY, 1912.

Date — Maximum, minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"
1	Max	46.9	45.9	44.8	47.4	45.9	44.7	45.2	44.6	43.5	46.2	44.9	44.	42.1	33.2	35.9
	Min	44.9	44.9	44.4	44.9	44.9	44.4	44.8	44.5	43.4	44.9	44.5	43.9	41.9	32.3	35.5
2	Max	54.	49.8	45.	55.	45.3	45.2	49.3	45.	43.9	51.5	45.9	44.4	44.2	35.	37.1
	Min	44.3	44.7	44.2	44	44.9	44.2	45.	44.4	43.5	45.1	44.4	41.1	42.1	34.4	36.9
3	Max	58.	53.	47.2	58.8	53.	47.1	53.	48.	44.9	55.9	48.5	46.	48.9	40.	40.8
	Min	49.2	49.	46.4	48.9	48.4	46.3	49	46.	44.4	49.9	47.	45.4	46.6	38.	38.9
4	Max	59.9	55.	48.8	60.4	55.6	49.	56.	49.5	46.3	58.	50.	48.6	52.2	45.4	43.4
	Min	51.4	51	48	51	50.3	47.4	51.6	49.	45.8	52.4	49.5	47.2	50.4	43.8	42.3
6	Max	63.	57.5	51.3	63.5	57.2	51.3	59.	52.8	48.9	61.	53.	50.3	56.9	50.4	47.6
	Min	53.2	53	50.2	52.4	52.1	50	53	51.8	48	51.4	52.	49.7	54.8	49.	46.4
7	Max	63.5	59.5	53.	63.8	59.	52.5	61.	54.6	49.9	62.8	55.	52.	59.8	52.1	48.8
	Min	56.8	56.4	52.3	56.4	55.7	52	58	54.2	49.8	58.2	54.4	51.7	58	52	48.4
8	Max	59.8	57.4	53.4	60.	56.7	52.8	58.4	55.4	51.2	59.5	55.5	53.	59.8	54.5	50.4
	Min	55	55	52.8	54	54	52.4	56.9	55.	50.8	57.1	54.4	52.8	59	53.8	49.5
9	Max	59.3	55.8	53.	60.2	55.5	52.5	56.2	54.8	51.7	58.	55.	53.1	58.5	55.	51.8
	Min	51.5	53.	51.8	50.	52.1	51.2	54.	53.2	50.8	54.3	53.8	52.	57.3	54.	51.4
10	Max	63.	58.	52.4	64.5	58.	52.2	59.	53.5	51.	60.9	54.	52.	58.4	54.5	52.
	Min	51	52.8	52	50.5	52.	51.5	54	53.3	50.5	53.9	53.5	52.	56.8	54.3	51.2
11	Max	57.4	57.	53.5	56.5	56.	53.5	58.	55.2	51.	58.2	55.8	53.	59.9	55.	52.
	Min	55.5	54.9	52.2	55	54.3	52	56	54.	50.4	56.1	51	52.	57.9	54.8	51.5
13	Max	51.3	49.5	49.	53.	50.	49.	49.9	50.4	50.2	50.5	50.	50.6	51.	54.	53.
	Min	43	45.8	48.3	43.5	46.1	48.6	47.4	49.5	49.9	46.	49.	50.5	50.3	53.	52.6
14	Max	54.	51.7	49.4	56.	52.5	49.8	51.8	50.	49.2	53.8	50.3	49.8	52.2	52.	52.
	Min	45.9	46.9	47.5	46.	47.5	48.4	47.2	48.4	48.	47.8	48.3	48.5	50.1	51.2	51.
15	Max	48.6	48.4	49.	48.4	48.5	50.1	48.9	50.	49.1	49.9	50.4	50.	51.5	51.7	51.5
	Min	47.	48.	48.5	46.2	48.	49.	48.	49.	48.9	49.	49.5	49.5	50.	51.	51.
16	Max	49.4	48.3	48.1	49.5	48.2	48.8	48.8	48.7	48.5	49.8	49.2	49.0	49.7	50.5	51.
	Min	47.	47.8	48.	47.	47.8	48.4	48	48.6	48.4	48.2	48.5	48.8	49.3	50.	50.4
17	Max	54.	51.	48.	49.5	51.	48.	50.3	48.2	47.9	52.5	48.3	48.4	49.5	49.5	49.8
	Min	46.8	47.	47.1	45.8	46.9	47.	47.2	47.9	47.2	47.7	47.8	47.9	48.4	48.9	49.
18	Max	50.4	48.6	48.5	52.8	49.1	48.	50.2	48.9	47.4	49.8	48.7	48.2	49.4	49.1	49.5
	Min	45.8	47.2	47.2	46.5	48.5	47.6	48.2	47.8	46.8	48.5	48.5	48.1	49.	48.2	48.6
20	Max	55.1	53.	50.	55.4	52.6	50.	52.6	50.	49.3	54.4	51.3	50.	52.6	50.2	49.6
	Min	49.5	49.9	49.5	49.2	49.5	49.7	50.	49.9	48.8	50.9	50.5	49.4	51.	49.2	48.9
21	Max	59.5	56.3	52.	59.8	55.8	51.8	56.4	52.	50.	58.	52.9	51.8	55.1	53.5	50.
	Min	52.4	51.7	49.5	51.9	51.	49.5	51.9	50.1	48.2	52.6	50.5	49.5	52.4	49.5	48.8
22	Max	64.2	59.8	53.7	67.9	60.1	53.7	59.8	54.	50.9	62.2	55.	52.5	58.1	52.9	50.8
	Min	56	55.2	52.7	55.5	54.5	52.8	56.	53.2	50.7	56.4	54.	52.4	56.3	52.3	50.7
23	Max	69.8	63.7	56.	71.7	63.7	56.1	63.5	56.4	52.4	67.	58.	54.8	61.8	55.	51.9
	Min	60.3	59.1	55.2	60.8	59.	55.4	59.8	55.9	52.	61.1	57.2	54.1	60.3	52.	51.5
24	Max	67.5	63.7	58.7	68.6	63.5	57.9	64.2	59.4	54.5	66.9	60.8	57.2	64.9	58.7	53.3
	Min	64.0	62.2	58.1	63.2	61.4	57.3	63.2	59.	54	64.4	59.7	56.8	63.7	56.9	53.
25	Max	69.8	63.9	57.8	71.3	63.5	57.5	64.	59.3	55.7	67.1	60.2	57.3	63.7	58.8	55.3
	Min	58.7	59.3	57.	57.	58.2	56.9	60.3	58.5	55.	61.1	59.3	57.1	62.4	58.4	54.5
27	Max	67.3	64.3	60.2	67.7	63.3	59.9	65.5	61.9	57.1	66.8	62.6	59.3	66.4	60.9	57.1
	Min	64.4	63	59.8	64	61.9	59.2	61.3	61.3	56.9	64.9	61.9	59.2	65.5	60.8	56.5
28	Max	64.5	63.	59.9	64.2	62.3	59.8	64.9	61.8	57.9	65.2	62.3	59.8	66.8	62.	58.3
	Min	[illegible]	62.6	59.5	63.5	61.8	59.2	64.	61.3	57.8	64.4	61.9	59.6	66.	61.6	57.9
29	Max	60.2	60.7	59.5	59.3	60.	59.1	62.3	61.5	58.2	62.1	61.4	59.8	65.	62.5	59.2
	Min	58.8	58.9	58	58	58	58	60.1	60.1	57.9	59.8	59.8	59.	63.	62.1	59.1
30	Max	66.	61.3	56.7	68.8	62.	56.8	61.3	58.3	57.1	63.4	58.	57.9	61.8	61.	59.1
	Min	54.5	55.9	56	53.5	55.1	56	57	57.3	56.3	56.3	57	56.7	60	60.	58.7
31	Max	70.4	64.3	58.	72.	64.3	58.2	64.3	59.	56.9	67.	59.6	58.2	63.1	61.	58.3
	Min	58.8	59.3	58	58	59.5	58.1	60.3	58.6	56.3	60.3	59.4	57.5	61.8	60.	58.1
Monthly range		6.59	3.18	0.83	7.76	3.28	0.47	2.92	0.78	0.52	4.14	0.97	0.59	1.81	0.98	0.62

DAILY TEMPERATURE FLUCTUATIONS FOR MAY — 1912

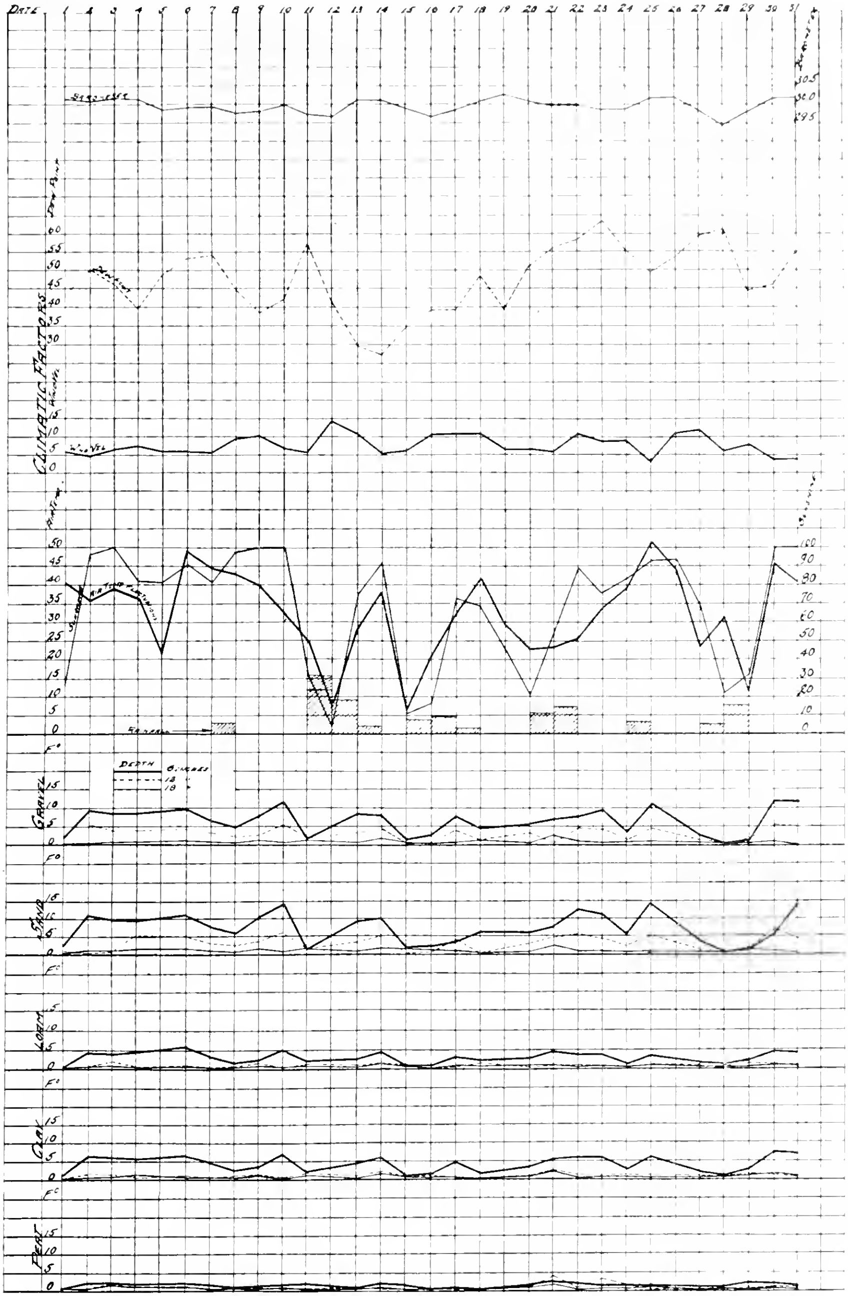

FIG. 21.

Y MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, JUNE 1912.

Day		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6	12	18"	6"	12"	18	6	12"	18"	6"	12"	18"	6"	12"	18"
	Max	72.8	67.	60.	73.7	66.1	60.	65.	61.9	57.3	69.8	62.3	59.8	67.	61.5	58.8
	Min	[illegible]	62.8	59.3	61.9	61.9	59.	61.8	60.5	57.	63.9	61.	59.	64.4	60.6	58.
	Max	70.5	65.7	60.3	71.6	65.1	59.9	65.1	61.9	59.	68.1	62.	60.2	65.9	62.3	59.8
	Min	[illegible]	61.5	59.1	58.8	59.9	59	62	60.9	58.3	61.8	61.	60	64	62.	59.1
	Max	66.9	63.8	61.	68.	64.	60.6	64.4	62.8	59.	66.	62.8	60.6	66.8	62.8	60.
	Min	62.8	62.5	60.5	61.2	61.3	[illegible]	63.4	62	58.9	63.9	62.1	60.5	65.9	62.8	59.8
	Max	66.8	62.7	60.1	67.5	62.8	59.9	63.	61.4	59.1	65.	61.9	60.4	64.8	62.9	60.4
	Min	57.9	59.1	59	56.5	58.6	58.7	60.	60	58.3	60.3	60.3	59.5	63.	62.3	60.
	Max	70.	65.5	60.1	70.	65.3	60.1	65.8	61.	58.4	67.7	61.8	59.9	65.4	62.2	60.1
	Min	62.3	62	59.9	61.7	61.3	59.7	62.3	60.9	58.3	63.	61.1	59.8	64.2	62.	60.
	Max	68.6	64.1	61.	68.8	63.7	60.3	64.3	62.	59.	66.7	62.2	60.5	64.6	62.3	60.3
	Min	60	60.8	59.9	58.2	59.9	59.3	61.2	60.70	58.6	61.9	61.9	59.9	63.1	62.	60.
	Max	68.	64.4	60.5	67.8	63.4	59.9	64.3	61.5	58.9	65.9	61.8	60.1	64.	62.1	60.2
	Min	59.2	60.4	59.5	57.6	[illegible]	59	60.7	60.4	58.5	61.	60.4	59.8	62.4	61.8	60.
10	Max	71.2	66.1	61.2	71.7	65.7	60.9	66.8	62.1	59.1	68.4	62.4	61.3	65.7	62.8	60.7
	Min	61.6	61.9	60.3	60	60.9	59.9	62.6	61.3	58.9	63.1	61.3	60.1	63.7	61.8	59.9
11	Max	71.2	66.3	62.	71.2	65.7	61.4	67.1	63.	59.9	68.2	63.	61.3	66.	62.4	60.1
	Min	62.8	62.8	60.9	61.1	61.9	60.3	63.5	62.0	59.3	61.9	62.1	60.5	64.3	62.2	60.0
12	Max	72	67.8	62.5	71.7	66.5	62.3	68.6	64.	60.9	69.9	64.	61.8	67.9	63.3	60.5
	Min	66.5	65.1	62.2	65.9	64.9	62.1	66.9	63.8	60.3	66.9	63.8	61.8	67	62.8	60.3
	Max	72.5	67.9	63.	71.8	66.5	62.3	68.8	64.6	61.	69.9	64.4	62.5	67.8	63.9	61.1
	Min	63.8	63.9	62.1	62.1	62.8	61.7	65	63.9	60.9	65	63.9	62.1	66.	63.9	61.
14	Max	65.6	65.7	63.8	64.2	64.3	63.	66.6	65.	61.7	66.	65.	62.9	68.	64.3	62.
	Min	[illegible]	63.4	62.1	63	62.5	61.4	61.7	63.8	61.3	64.6	63.7	62.5	65.9	64.	61.8
15	Max	70.3	66.2	61.8	71.	66.	61.3	67.3	62.7	60.7	68.6	62.8	61.5	66.5	63.3	61.7
	Min	62.8	62.2	61.2	62.1	61.8	60.7	63.6	62.4	60.5	63.2	62.3	61.2	64.8	63.2	61.5
	Max	72.	67.6	63.5	72.5	67.2	63.1	68.	64.8	61.5	69.4	64.5	63.	68.2	64.7	62.
	Min	63	63.6	62.3	62.6	63.	62	64.8	63.9	61.3	65.	63.9	62.2	66.9	64.5	62.
	Max	69.	65.4	63.2	69.	64.6	62.7	66.2	64.5	61.3	66.9	64.6	63.	67.7	64.9	62.3
	Min	63	63	62.3	61.5	62	61.7	63.8	63.4	61.2	63.7	63.3	62.2	65.6	64.4	61.8
	Max	70.5	66.9	62.7	70.4	66.	62.1	67.7	63.7	61.1	68.7	63.7	62.2	66.9	64.1	62.2
	Min	[illegible]	[illegible]	62.2	62.5	63.	61.6	64.7	63.3	61.	61.	63.2	62	65.6	64.	62.
	Max	70.8	66.6	62.9	70.8	65.8	62.2	67.4	63.7	61.4	68.6	63.6	62.3	66.6	64.2	62.1
	Min	[illegible]	63.4	62.3	62	62.5	61.7	64.2	63.3	61.	64.1	63.3	62.	65.6	63.9	61.9
	Max	72.	67.5	63.2	71.6	66.3	62.7	68.3	64.3	62.5	69.	64.2	62.8	67.4	64.5	62.5
	Min	[illegible]	64.1	[illegible]	63	63.2	62.3	65.	63.9	61.3	65.	63.9	62.4	66.4	64.2	62.0
	Max	74.3	69.	63.6	73.5	67.4	63.1	69.8	64.8	62.	71.	64.7	63.	68.2	64.8	62.5
	Min	[illegible]	64.4	65	62.8	63.5	62.6	65.4	64.4	61.8	64.7	64.1	62.9	66.4	64.6	62.2
	Max	74.	70.	66.	73.	68.5	65.2	71.2	67.1	63.3	71.0	66.7	64.5	70.8	66.3	63.2
	Min	68.4	[illegible]	65.3	67.3	66.0	64.5	68.8	66.5	63.0	68.0	66.2	64.3	69.6	66.0	62.9
	Max	77.0	71.4	66.1	75.6	69.8	65.1	72.7	67.3	64.0	74.5	66.8	65.0	71.2	67.1	64.0
	Min	67.8	67.5	65.3	66.5	66.0	64.4	68.7	66.5	63.5	68.4	66.5	64.5	69.6	66.4	63.5
	Max	77.0	72.5	66.9	75.0	70.7	66.0	73.9	68.4	64.6	74.5	68.1	65.8	73.0	68.0	64.7
	Min	[illegible]	69.2	66.4	68.0	67.7	[illegible]	70.3	67.8	63.6	69.5	67.3	65.1	71.0	67.1	63.7
	Max	75.2	71.2	67.5	73.4	69.4	66.3	72.5	69.0	65.0	73.0	68.7	66.2	72.5	68.6	65.1
	Min	[illegible]	[illegible]	66.4	[illegible]	67.5	[illegible]	70.0	68.0	64.7	69.7	67.5	65.5	71.3	68.1	65.0
	Max	77.5	72.3	67.1	75.4	70.3	66.0	73.9	68.6	65.0	74.8	68.3	66.0	73.0	68.8	65.7
	Min	[illegible]	[illegible]	[illegible]	67.7	[illegible]	65.3	70.0	68.0	64.8	69.4	67.3	65.8	71.0	68.3	65.2
	Max	74.8	70.2	67.9	73.3	69.1	66.8	71.9	69.5	65.3	72.3	69.0	66.7	73.5	69.3	65.9
	Min	70.2	[illegible]	[illegible]	69.2	68.2	[illegible]	71.1	66.1	62.9	70.9	66.0	63.8	71.5	66.3	63.2
Monthly range		7.56	3.32	0.92	6.43	3.32	0.95	3.09	0.87	0.47	4.56	0.90	0.56	1.62	0.48	0.44

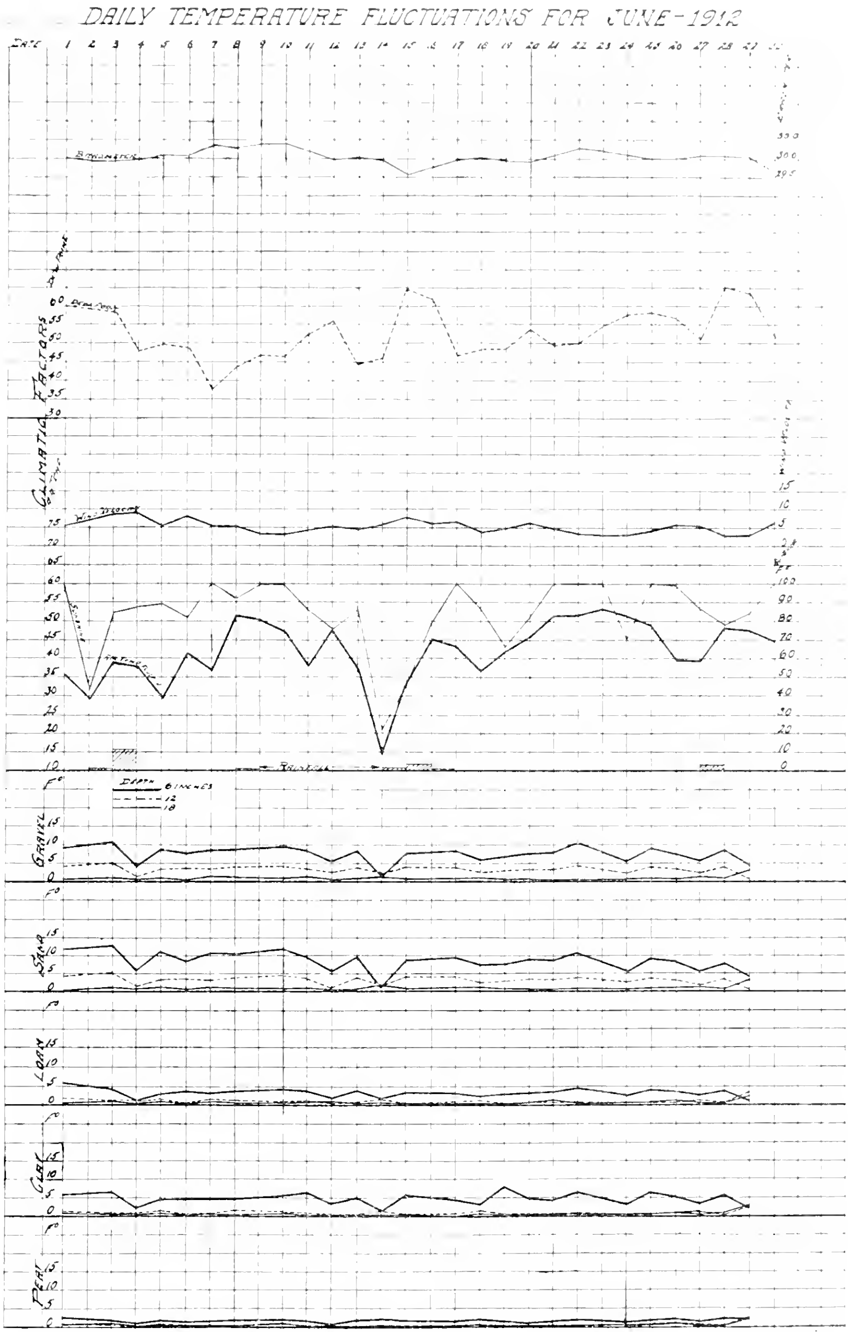
DAILY TEMPERATURE FLUCTUATIONS FOR JUNE-1912
DATE
BAROMETER
CLIMATIC FACTORS
DEPTH
6 INCHES
12
18
GRAVEL
SAND
LOAM
CLAY
PEAT

FIG. 22.

TABLE 37. DAILY MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, JULY, 1912.

Date. Maximum. Minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
1	Max	76.3	71.4	68.7	74.0	69.3	67.4	72.6	70.3	66.3	73.2	69.8	67.8	73.3	70.4	67.0
	Min	68.0	68.1	66.5	67.0	66.3	65.5	69.1	68.2	65.3	69.2	67.7	66.1	71.8	69.1	66.0
2	Max	76.5	71.8	68.8	74.3	69.7	67.5	73.3	70.2	66.5	73.8	70.0	67.6	74.0	70.3	67.2
	Min	70.7	68.7	66.4	69.0	67.1	65.3	70.1	68.0	64.7	69.7	67.5	65.3	71.2	6 90	66.0
3	Max	79.8	75.0	69.2	77.2	72.4	68.0	76.5	70.8	66.9	77.1	70.3	68.2	76.1	71.1	67.5
	Min	72.0	71.3	68.8	71.0	70.0	67.8	73.0	70.5	66.5	72.4	70.0	67.6	74.3	70.2	66.8
4	Max	80.4	75.0	69.4	77.6	72.4	68.0	76.6	71.0	66.6	77.6	70.3	67.9	76.1	70.8	67.2
	Min	71.9	70.6	68.0	70.8	69.0	67.0	72.1	69.9	66.0	71.9	69.3	67.3	73.4	70.0	66.3
5	Max	80.0	75.6	71.0	77.8	73.2	69.4	77.4	72.4	67.8	77.9	71.3	68.7	77.0	71.5	67.5
	Min	74.8	72.7	69.6	73.0	71.1	68.2	74.7	71.3	67.0	74.1	71.0	68.4	75.6	71.2	67.0
6	Max	80.8	77.1	71.5	78.6	74.6	70.2	78.9	73.4	69.1	79.2	72.9	70.2	78.5	73.4	69.0
	Min	74.9	73.8	71.0	74.0	72.1	69.5	75.7	72.7	68.5	74.8	71.9	69.3	76.2	72.0	67.8
8	Max	80.8	75.7	70.6	80.3	74.3	69.6	77.4	72.3	69.0	78.4	71.9	70.0	77.3	73.2	69.8
	Min	72.5	71.9	70.0	71.3	70.8	69.1	73.7	72.0	68.7	73.0	71.3	69.6	75.5	72.9	69.6
9	Max	83.1	77.2	71.4	81.5	75.5	70.4	78.5	73.0	69.0	79.7	72.3	70.3	78.1	73.5	69.9
	Min	74.2	73.0	70.4	73.0	71.7	69.5	75.0	72.2	68.3	74.3	71.7	69.7	76.2	72.9	69.3
10	Max	82.5	78.8	73.2	80.4	76.8	72.3	80.3	75.0	71.0	80.7	74.8	72.0	80.4	75.0	71.3
	Min	76.4	75.1	72.2	75.3	73.8	71.3	77.0	74.0	69.5	76.3	73.4	71.0	78.1	74.0	70.0
11	Max	83.7	78.8	73.7	81.2	76.5	72.5	80.4	75.4	71.1	81.0	75.0	72.7	80.0	75.7	71.6
	Min	76.2	75.5	73.1	75.1	74.0	72.0	77.2	74.8	71.0	75.3	74.0	72.0	78.2	75.2	71.4
12	Max	81.5	77.7	74.0	79.3	75.4	72.8	79.4	75.8	71.3	79.6	75.0	72.3	79.3	75.9	72.0
	Min	75.6	75.0	73.0	74.1	73.3	71.9	76.6	75.0	71.2	75.7	74.0	72.1	78.0	75.6	71.8
13	Max	76.3	76.1	74.0	75.3	74.9	72.7	77.9	75.9	71.8	76.7	75.0	72.9	79.4	75.9	72.3
	Min	74.0	73.8	72.2	72.4	72.8	71.2	75.3	74.3	71.3	74.6	73.2	72.0	76.7	75.3	72.2
15	Max	80.0	76.9	72.3	80.2	76.4	72.0	78.0	73.9	70.3	79.4	73.8	71.5	78.0	74.4	71.8
	Min	74.5	74.2	71.9	74.1	74.0	71.0	75.1	73.0	70.0	75.9	72.9	71.0	76.2	73.9	71.2
16	Max	78.4	73.9	72.0	79.0	73.3	71.3	75.0	73.6	70.6	76.1	73.2	71.9	75.7	74.2	71.7
	Min	69.0	70.0	70.2	66.3	68.8	69.7	71.4	71.9	70.0	71.0	71.6	70.8	73.7	73.4	71.3
17	Max	81.8	76.6	71.9	82.3	76.1	71.3	77.8	73.2	70.3	78.9	72.9	71.2	76.9	73.6	71.4
	Min	73.0	72.5	71.0	71.5	71.6	70.2	73.8	71.9	69.4	73.1	71.3	70.0	74.2	72.7	70.4
18	Max	74.0	74.5	73.0	72.0	73.1	72.2	75.7	74.0	70.7	74.3	73.5	71.7	77.3	74.0	71.2
	Min	71.3	71.3	71.3	70.1	70.2	70.3	72.6	72.9	70.2	71.5	72.0	71.2	74.3	73.8	71.0
19	Max	71.1	68.1	69.2	72.0	68.2	68.4	69.4	71.1	70.0	70.2	70.1	70.2	71.4	72.9	71.2
	Min	63.6	64.8	66.8	61.6	63.8	66.1	66.0	68.6	68.2	65.1	67.8	68.1	69.1	71.3	70.3
20	Max	65.6	66.4	67.2	64.9	66.0	67.0	67.6	68.8	67.4	66.9	68.0	67.7	70.3	70.5	69.8
	Min	65.2	65.6	66.2	64.2	65.2	66.0	66.7	67.5	67.0	66.3	67.0	67.1	68.9	70.0	69.3
22	Max	71.0	67.3	65.1	73.8	68.1	65.0	67.9	65.8	65.3	69.6	65.4	65.5	66.9	67.7	67.7
	Min	66.3	64.0	64.2	62.5	63.6	64.0	64.6	65.0	64.6	64.3	64.6	64.8	65.4	66.4	66.5
23	Max	69.3	67.6	66.	70.1	68.0	66.2	68.0	66.2	65.0	69.2	66.5	65.8	68.0	66.8	66.2
	Min	65.5	66.0	65.8	65.6	66.3	66.0	66.5	66.0	64.7	67.0	66.2	65.5	67.3	66.6	66.1
24	Max	73.0	69.8	66.2	73.4	69.9	66.2	70.1	66.9	65.4	71.5	67.0	66.1	68.7	66.9	66.1
	Min	67.5	67.0	66.0	67.3	66.9	66.0	67.7	66.2	64.7	67.9	66.6	65.5	67.9	66.2	65.3
25	Max	76.1	72.2	68.0	78.0	73.0	68.1	72.9	68.7	66.0	75.0	69.0	67.2	71.6	68.0	66.3
	Min	70.1	69.4	67.6	69.1	69.3	67.6	70.2	68.2	65.8	70.7	68.3	66.9	70.3	67.6	66.1
26	Max	73.0	70.1	69.0	73.6	70.1	69.0	70.8	69.9	66.9	72.2	70.1	68.3	71.4	69.9	67.3
	Min	68.3	68.2	68.0	67.9	68.0	67.8	69.0	68.9	66.8	69.3	69.1	68.0	70.0	69.1	66.8
27	Max	74.8	70.1	67.2	75.6	70.0	67.0	71.0	68.2	66.1	72.7	68.5	67.7	69.3	68.2	66.8
	Min	[illegible]	[illegible]	66.1	64.2	65.9	66.0	67.3	67.1	65.5	67.4	67.1	66.2	68.0	67.7	66.3
29	Max	71.0	69.0	67.6	71.9	68.9	67.6	69.9	69.2	67.2	70.6	69.0	67.9	70.4	69.4	68.0
	Min	[illegible]	[illegible]	67.1	65.4	66.2	66.7	68.1	68.2	66.9	67.9	68.0	67.4	69.7	69.0	67.6
30	Max	69.8	68.1	67.0	70.1	68.2	67.0	69.0	68.3	66.9	69.9	68.1	67.5	69.6	69.1	68.0
	Min	64.8	65.4	66.1	[illegible]	65.0	65.9	66.1	67.2	66.4	66.2	67.2	67.0	68.2	68.9	67.7
31	Max	68.9	66.6	66.2	70.3	66.9	66.0	67.1	66.9	66.0	68.3	66.9	66.5	68.0	68.2	67.5
	Min	[illegible]	64.5	65.2	61.9	[illegible]	65.2	65.1	66.0	65.7	65.0	66.0	65.9	67.0	67.7	67.3
Monthly range		6.17	3.00	1.04	6.78	3.00	1.03	2.94	1.07	0.63	4.07	1.12	0.78	1.77	0.67	0.59

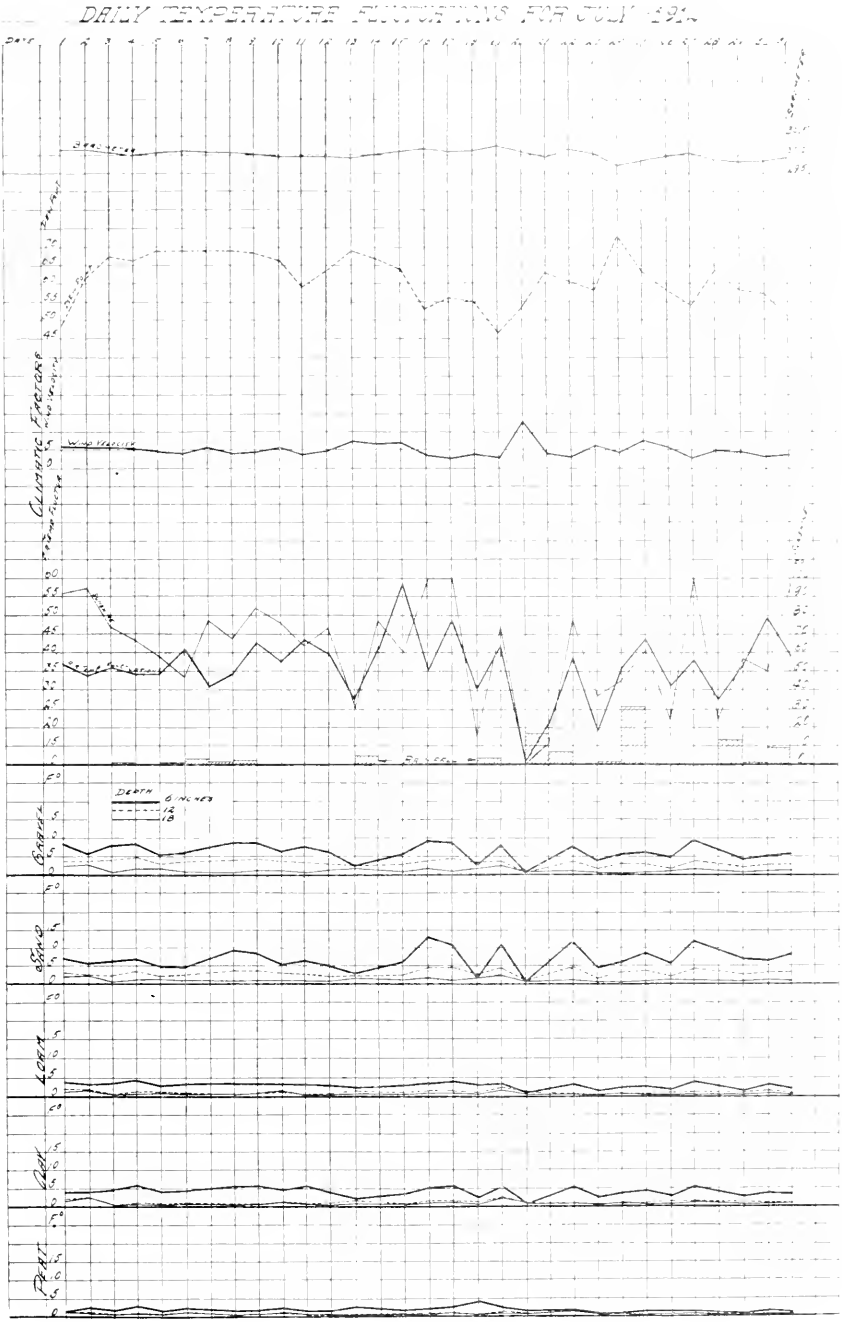
CLIMATIC FACTORS
WIND VELOCITY
DEPTH
6 INCHES
12
18
GRAVEL
SAND
LOAM
PEAT

FIG. 23.

TA[illegible] MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL AUGUST, 1912

[illegible]		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"
1	Max	69.0	66.1	65.5	69.9	66.5	65.6	66.1	66.2	65.4	68.0	66.2	65.0	67.1	67.5	66.9
	Min	62.1	65.5	64.4	61.9	63.3	61.5	63.8	65.0	64.6	64.3	65.0	65.0	65.9	66.3	66.1
2	Max..	66.7	65.6	65.2	66.1	65.2	65.3	65.9	65.7	64.3	66.4	65.9	65.4	66.1	66.1	66.0
	Min	64.0	64.4	64.8	63.4	64.0	64.6	64.8	65.0	64.7	65.0	65.2	65.1	65.8	66.0	66.0
3	Max	63.4	62.4	64.0	64.2	62.6	63.7	62.9	64.6	64.3	63.3	64.4	66.1	64.5	65.6	65.5
	Min	59.4	61.0	62.8	58.0	60.5	62.6	61.2	63.2	63.6	61.0	63.0	64.0	63.2	65.0	65.3
5	Max	71.4	67.6	64.1	72.6	67.8	64.2	67.7	64.0	63.1	69.3	64.3	63.7	65.9	64.2	64.3
	Min	62.8	63.3	[illegible]	62.0	63.2	63.3	63.4	63.4	62.7	63.8	63.5	63.2	64.0	63.9	63.9
6	Max..	72.1	68.6	65.1	72.9	68.9	65.1	69.0	65.2	63.8	70.2	65.7	64.5	67.1	64.9	64.1
	Min..	67.2	65.4	65.0	64.2	65.0	64.8	65.7	65.4	63.3	65.9	65.2	64.2	66.0	64.5	64.0
7	Max	72.3	69.7	66.1	73.0	69.5	66.1	70.1	66.5	64.8	71.2	66.7	65.4	63.8	65.9	64.9
	Min	67.4	67.0	65.9	66.9	66.6	65.7	67.5	66.2	64.4	67.9	66.2	65.3	67.3	65.4	64.4
8	Max	73.3	69.9	66.5	74.1	69.9	66.2	70.5	67.1	65.0	71.7	67.2	66.0	69.3	66.4	65.0
	Min.	67.5	67.2	66.1	66.8	66.7	65.9	68.0	66.9	65.0	68.2	66.9	65.9	68.3	66.2	64.9
9	Max	71.	69.4	66.9	71.1	69.0	66.9	70.2	67.8	65.6	70.8	68.8	66.3	70.0	67.0	65.3
	Min	68.6	67.5	66.0	67.9	67.8	66.7	68.5	66.9	64.8	68.9	67.1	65.9	69.2	66.5	64.8
10	Max	69.9	67.9	66.7	71.0	67.9	65.1	68.9	67.8	65.8	69.4	67.5	66.5	69.4	67.5	65.9
	Min	66.2	66.1	65.9	65.3	65.8	65.4	67.1	66.9	65.2	67.0	66.6	65.9	68.4	67.0	65.6
12	Max	70.9	68.0	65.9	72.9	68.4	65.7	68.8	66.6	65.2	70.0	66.3	65.9	68.2	67.3	66.1
	Min.	65.3	65.3	64.5	64.5	64.7	64.3	65.9	65.3	64.3	66.1	65.1	64.9	66.6	66.2	65.5
13	Max	75.0	71.0	66.9	77.0	71.4	66.8	71.4	67.1	65.0	73.2	67.4	66.0	70.9	67.1	65.8
	Min	68.3	67.8	66.0	68.6	67.9	66.0	68.3	66.5	64.6	69.3	66.7	65.5	69.3	66.6	65.2
14	Max	76.9	72.6	68.6	77.9	72.7	68.3	73.1	69.0	66.0	74.9	69.2	67.2	72.2	68.3	66.0
	Min....	69.9	69.3	67.8	69.3	68.9	67.3	70.0	68.3	65.7	70.8	68.7	67.1	71.0	68.0	65.8
15	Max	73.2	70.3	69.4	73.9	70.0	69.0	71.0	70.0	67.0	71.9	70.0	68.3	72.1	69.3	66.7
	Min.	68.3	68.2	67.8	67.0	67.3	67.2	69.0	68.8	66.5	68.9	68.6	67.5	70.5	69.0	66.6
16	Max	73.4	69.9	68.2	73.9	69.6	67.7	70.6	69.3	67.0	71.3	69.0	68.0	70.4	69.3	69.3
	Min	66.0	66.5	66.5	64.5	65.5	64.2	67.3	67.7	66.1	66.9	67.4	66.5	68.8	68.4	67.0
17	Max	69.4	67.7	67.6	69.6	67.0	67.1	68.4	68.4	66.1	68.3	68.0	67.1	69.8	68.4	67.1
	Min	66.0	66.3	66.2	65.2	65.6	66.0	67.1	67.2	66.1	66.4	66.7	66.4	68.5	68.1	66.6
19	Max	70.7	70.0	68.2	70.2	69.4	68.0	71.0	68.9	66.1	70.1	68.8	67.0	71.2	68.2	66.7
	Min...	69.4	69.0	67.3	69.0	68.3	67.0	69.9	68.2	66.0	69.4	68.0	66.8	70.2	68.2	66.5
20	Max	72.8	70.0	67.5	74.0	69.8	67.2	70.7	68.4	66.4	71.3	68.0	67.1	70.2	68.3	66.8
	Min	68.0	67.4	66.7	67.4	66.9	66.3	68.2	67.5	65.9	68.0	67.5	66.7	69.3	68.3	66.6
21	Max	74.3	71.0	68.0	75.9	71.5	68.0	71.8	69.0	67.0	73.1	68.9	67.5	71.2	69.2	67.8
	Min	67.5	67.5	67.2	67.2	67.2	66.9	68.3	68.0	66.0	68.3	67.8	67.0	69.6	68.5	66.9
22	Max	71.2	70.0	69.0	71.3	70.0	69.0	70.7	69.6	67.4	71.1	69.7	68.3	71.0	69.5	68.0
	Min	68.3	68.4	68.2	67.6	68.2	68.0	69.2	69.0	67.3	69.6	69.0	68.1	70.2	69.4	67.9
23	Max.	68.7	67.1	67.7	68.1	67.0	67.4	67.7	68.8	67.3	68.2	68.4	68.0	69.1	69.3	68.1
	Min	65.0	65.6	66.2	64.0	65.2	66.2	66.2	67.3	66.5	66.0	67.1	67.1	67.8	68.8	66.9
24	Max	71.7	67.5	66.0	72.7	67.6	65.9	67.8	66.9	66.1	69.3	66.4	66.4	66.6	68.0	67.8
	Min	62.8	63.8	64.8	61.7	63.4	64.5	64.2	65.4	65.2	64.3	65.4	65.3	65.3	66.8	66.8
26	Max	79.2	75.3	70.4	79.3	75.0	70.1	76.1	71.0	67.5	77.2	71.0	68.9	74.8	69.4	66.9
	Min	72.5	71.7	69.0	71.8	71.3	68.9	72.4	69.0	65.6	72.3	69.3	66.9	72.4	67.2	65.4
27	Max	75.0	72.1	70.3	75.0	71.6	69.9	72.7	71.2	68.7	73.2	71.0	69.4	73.0	70.6	68.3
	Min	69.0	69.5	69.4	67.9	68.7	69.0	70.1	70.3	68.0	69.7	69.9	69.2	71.6	70.0	67.4
28	Max	68.1	69.3	69.6	67.0	68.7	69.0	70.1	70.7	68.5	69.0	70.0	69.2	71.7	70.7	68.7
	Min	65.5	66.0	66.9	64.6	65.4	66.1	67.0	68.0	67.2	66.3	67.3	67.3	69.4	68:0	68.0
30	Max	62.0	62.6	64.6	61.8	62.0	64.4	63.5	65.2	65.0	66.2	64.9	65.0	66.9	66.0	66.9
	Min	60.3	61.0	62.2	59.1	60.5	62.0	61.7	63.0	63.1	62.0	62.3	63.5	65.6	63.8	65.8
[illegible]	Max	67.0	65.6	65.8	67.3	65.3	65.2	66.	66.8	66.3	66.6	66.1	66.2	68.4	67.0	67.8
	Min	63.1	63.8	65.0	62.2	63.4	64.6	64.6	65.6	65.6	64.0	65.4	65.8	67.9	66.0	67.7
31	Max	71.7	67.0	63.2	73.9	67.4	63.6	67.2	63.3	62.8	69.3	63.5	63.0	65.7	64.6	65.1
	Min	60.6	61.4	62.0	60.0	61.0	61.8	61.7	62.8	62.8	61.4	62.4	62.7	63.4	63.2	64.7
Monthly range		5.22	2.63	1.08	6.59	2.95	1.26	2.56	3.31	0.60	3.42	1.12	0.70	1.34	0.75	0.51

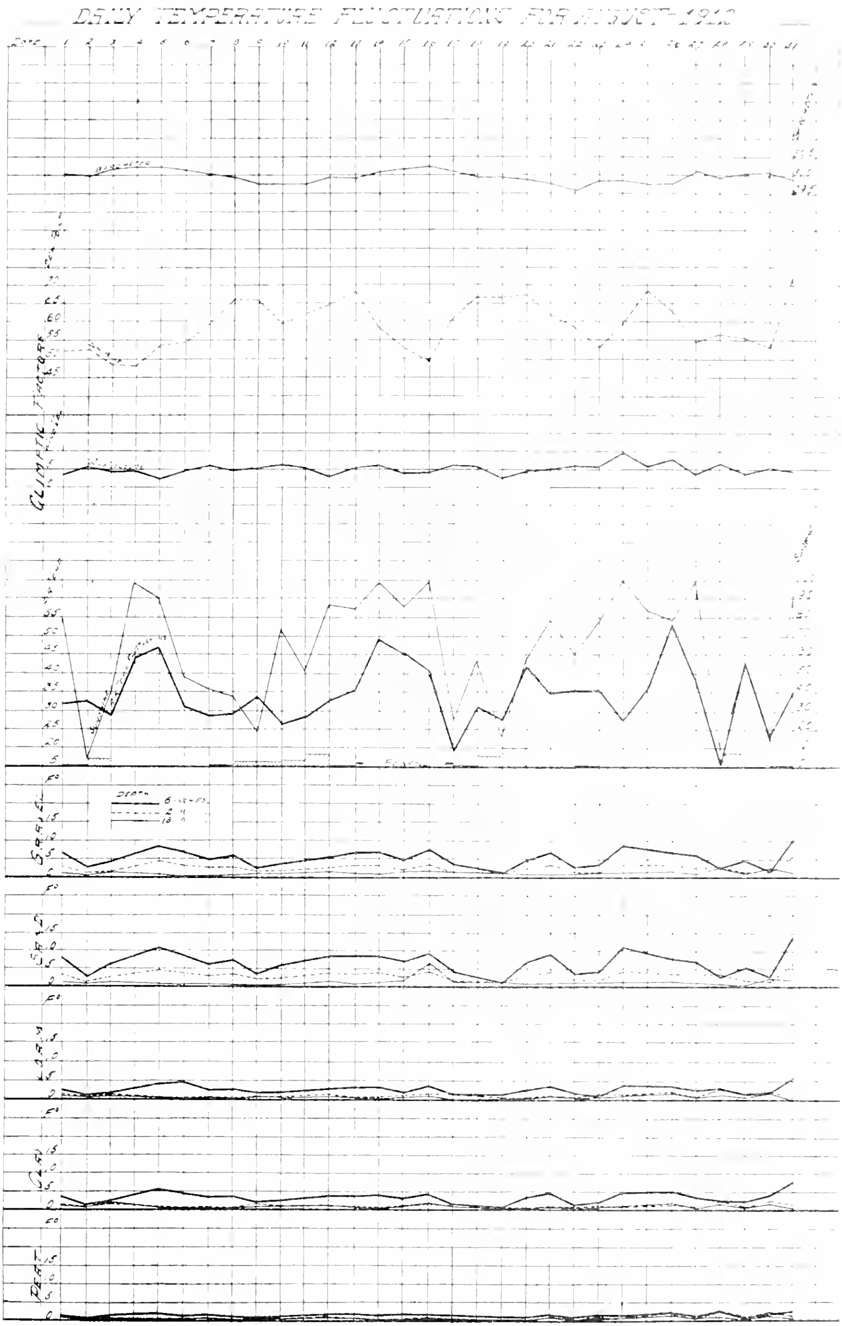

FIG. 24.

TABLE [illegible]. DAILY MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, SEPTEMBER, 1912.

Date. Maximum, Minimum.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"	6	12	18"
2	Max	38.5	73.9	68.9	79.2	73.9	68.6	74.0	69.1	66.0	75.9	69.4	67.2	72.9	67.8	65.6
	Min	51.3	70.2	68.0	71.0	70.0	68.0	71.2	68.5	65.6	71.2	68.7	67.1	71.2	67.4	65.3
3	Max	77.0	73.2	70.0	78.2	73.3	69.3	74.4	70.4	67.6	75.0	71.0	68.8	73.9	69.3	66.6
	Min	71.6	70.9	69.3	70.8	70.2	69.0	72.0	70.0	67.0	71.9	69.9	68.1	72.6	69.0	66.2
4	Max	76.1	73.0	70.5	77.0	72.8	70.0	74.0	71.4	68.7	74.2	71.2	69.6	74.0	71.0	68.7
	Min	71.1	70.5	69.8	70.2	70.0	69.4	72.7	71.0	68.3	70.8	70.5	69.4	73.4	70.4	67.8
5	Max	77.1	74.0	70.3	77.3	73.9	70.2	75.1	71.6	69.6	75.2	71.2	69.9	74.6	71.2	69.0
	Min	71.2	71.3	69.8	70.2	70.6	69.5	72.4	71.1	68.8	71.2	70.4	69.1	72.9	71.0	68.9
6	Max	77.5	73.9	70.5	79.0	74.0	70.2	75.3	71.7	69.0	76.9	71.4	70.0	74.8	71.6	69.4
	Min	71.2	71.3	70.2	70.0	70.6	69.6	72.5	71.3	69.0	70.0	71.0	69.7	73.3	71.4	69.3
7	Max	78.5	73.7	71.2	79.8	74.8	70.8	75.9	72.1	69.4	76.3	72.0	70.3	75.4	72.0	69.9
	Min	71.8	71.4	70.8	71.0	71.0	70.2	72.9	72.0	69.1	71.3	71.5	70.1	74.4	72.0	69.4
9	Max	78.6	74.3	71.2	79.2	74.0	70.8	75.5	72.3	69.4	76.8	71.8	70.4	75.0	72.1	70.0
	Min	72.2	71.4	70.0	71.2	70.3	69.7	72.1	71.1	68.8	72.1	70.8	69.3	73.2	71.4	69.4
10	Max	79.8	75.6	72.2	79.8	75.3	71.9	76.8	73.2	70.1	77.4	73.0	71.1	76.0	73.0	70.7
	Min	73.1	72.8	71.6	71.9	71.7	71.1	73.7	72.8	70.0	72.0	72.2	71.0	74.8	72.7	70.2
11	Max	73.7	73.7	72.7	73.6	72.7	72.2	75.0	73.6	70.8	74.0	73.1	71.5	76.2	75.1	71.1
	Min	72.7	72.1	71.8	71.4	71.4	71.0	73.6	73.0	70.5	72.9	72.3	71.3	73.3	73.2	70.6
12	Max	71.0	69.0	69.8	71.7	68.7	69.3	69.8	71.4	70.2	70.5	70.6	70.6	72.6	72.3	71.0
	Min	64.4	66.0	68.0	62.8	65.4	67.1	67.1	69.2	69.2	66.3	69.0	69.3	69.9	71.7	70.9
13	Max	70.7	68.6	68.1	71.1	68.3	67.8	69.2	69.3	68.5	69.8	68.8	68.8	69.6	70.4	70.2
	Min	65.0	65.9	67.1	65.6	65.3	66.9	66.9	68.0	67.8	66.0	67.8	67.8	68.3	70.1	70.0
14	Max	68.0	67.1	67.3	67.8	66.7	67.2	68.0	68.2	67.0	68.1	68.0	67.8	68.9	69.0	69.0
	Min	65.8	66.0	66.1	65.2	65.6	66.3	66.6	67.5	66.1	66.4	67.0	67.1	67.8	68.6	68.3
16	Max	67.1	65.7	66.3	68.1	65.6	66.0	66.0	67.0	66.3	66.7	66.5	66.5	67.0	68.0	67.9
	Min	62.3	63.2	65.0	61.5	63.0	64.8	64.0	65.6	65.6	63.5	65.2	65.6	65.5	67.0	67.2
17	Max	62.6	63.7	65.4	62.3	63.5	65.3	64.4	66.0	65.5	63.9	65.6	66.0	66.1	67.5	67.3
	Min	61.6	62.7	64.3	60.9	62.6	64.3	63.5	64.9	65.1	62.9	64.4	65.2	64.7	66.4	66.8
18	Max	62.7	65.6	65.2	62.4	63.6	63.8	63.9	64.3	64.5	64.6	63.9	64.5	64.0	65.6	66.5
	Min	59.3	62.3	63.5	60.0	62.4	63.3	62.9	63.8	64.0	62.7	63.5	64.0	63.6	65.0	65.9
19	Max	60.8	61.4	63.6	60.1	61.2	63.6	61.8	63.8	63.9	60.7	63.8	64.5	63.4	65.1	65.8
	Min	58.9	60.3	62.0	58.4	60.2	62.2	60.4	62.8	63.4	59.6	62.1	62.9	61.9	64.1	65.4
20	Max	61.8	60.4	61.9	62.0	60.8	62.0	60.3	62.0	63.1	60.6	61.7	62.8	60.9	63.5	64.8
	Min	57.8	58.9	60.3	56.6	58.6	60.7	58.8	60.7	61.8	58.6	60.1	61.4	59.7	62.3	64.2
21	Max	65.1	62.5	61.9	66.9	63.8	61.6	62.8	61.8	61.8	63.9	61.7	61.8	61.3	62.6	63.8
	Min	59.1	59.6	60.6	58.9	59.6	61.1	59.4	60.7	61.3	59.5	60.6	61.4	60.3	61.6	62.6
23	Max	64.0	61.8	62.3	63.8	61.7	62.3	61.3	62.4	62.5	64.0	62.2	62.8	61.3	62.5	63.4
	Min	57.3	58.5	60.8	56.4	57.8	60.6	58.1	60.8	61.6	57.8	60.4	61.4	59.0	61.6	62.8
24	Max	62.1	60.5	61.1	62.0	60.2	60.6	60.1	61.0	61.1	60.6	61.0	61.2	59.9	60.7	62.1
	Min	57.7	57.4	60.4	56.5	58.5	59.9	58.5	59.8	60.5	58.4	59.5	60.3	58.8	60.4	61.7
25	Max	61.9	60.7	61.2	63.1	60.6	61.4	62.5	60.9	60.8	63.8	60.9	61.1	61.6	60.8	61.6
	Min	60.3	60.5	60.8	59.8	60.4	60.6	60.4	60.6	60.6	60.7	60.7	60.8	60.2	60.6	61.5
26	Max	61.8	61.9	62.4	62.2	62.0	62.6	62.0	62.2	61.7	61.9	62.6	62.2	62.1	61.7	61.9
	Min	59.3	60.5	61.7	59.0	60.4	61.6	60.3	61.5	61.3	60.2	61.3	62.0	60.8	61.4	61.9
27	Max	57.0	57.9	60.8	56.3	57.2	60.7	57.4	60.7	61.1	56.6	60.6	61.6	58.3	60.9	62.0
	Min	51.4	55.0	58.4	52.5	54.6	58.0	55.0	57.5	59.6	54.5	57.4	59.4	55.1	59.5	60.5
28	Max	53.5	55.3	58.0	52.8	55.2	58.2	55.4	58.0	59.3	55.0	57.9	59.0	56.0	59.5	61.2
	Min	53.2	54.6	57.0	52.5	54.7	57.1	51.2	56.9	58.8	53.8	56.5	58.4	54.9	58.8	60.6
30	Max	53.4	53.3	54.5	53.7	53.4	55.0	52.4	54.6	56.4	53.2	54.1	56.0	52.0	55.7	58.7
	Min	48.7	51.5	54.4	47.6	51.0	54.8	51.0	54.3	56.1	50.1	53.9	55.6	51.8	55.6	58.4
Monthly range		4.36	1.71	1.00	5.56	2.48	0.97	2.11	0.96	0.56	3.24	1.08	0.71	1.47	0.64	0.49

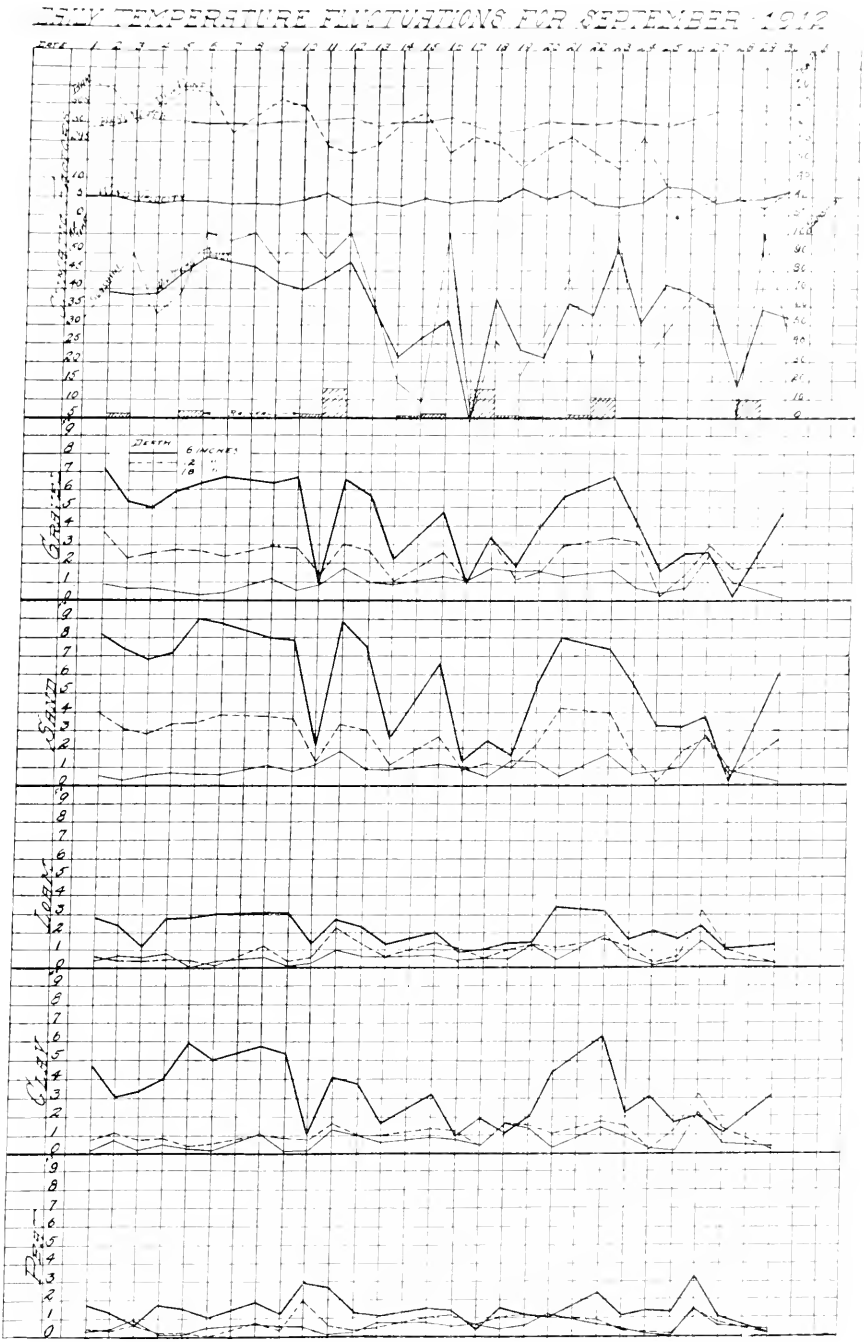
DAILY TEMPERATURE FLUCTUATIONS FOR SEPTEMBER 1912
DEPTH 6 INCHES
2 "
18 "
GRAVEL
SAND
LOAM
CLAY
PEAT

FIG. 25.

[illegible] MAXIMUM AND MINIMUM TEMPERATURES OF DIFFERENT TYPES OF SOIL, OCTOBER, 1912.

Day of Month.		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6	12	18	6	12	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
	Max	57.0	55.0	54.7	57.8	55.4	55.0	54.2	54.1	55.5	55.8	54.0	55.5	52.3	54.9	58.5
	Min	49.5	51.6	54.1	48.6	51.6	54.7	51.2	53.7	55.3	50.4	53.1	55.2	51.4	54.7	57.6
	Max	58.0	55.8	55.1	58.8	55.8	55.4	54.5	54.3	55.3	56.0	54.6	55.4	52.40	54.6	58.1
	Min	50.5	52.2	54.9	49.1	52.2	55.0	51.7	54.0	55.2	51.5	54.1	55.3	51.6	54.3	56.9
	Max	54.4	54.8	55.1	53.7	54.3	55.7	53.6	54.7	55.4	53.8	54.6	55.8	53.1	54.6	56.8
	Min	52.3	53.8	54.9	52.2	53.6	55.2	53.0	54.5	55.2	52.8	54.6	55.4	52.3	54.1	56.2
	Max	60.3	58.0	56.4	62.2	58.9	56.7	57.5	55.8	55.9	58.9	55.9	56.1	55.0	54.9	56.8
	Min	52.2	54.5	55.6	51.5	54.1	55.9	52.8	53.9	55.4	53.4	55.0	55.6	53.8	54.4	56.0
	Max	60.3	59.4	58.3	60.8	59.1	58.4	59.0	57.6	56.8	59.6	58.1	57.4	58.0	55.7	56.8
	Min	58.2	58.1	58.1	58.0	58.2	58.1	57.9	57.5	56.3	58.4	57.8	57.3	57.5	55.5	56.1
	Max	53.8	55.1	57.5	53.0	54.4	57.4	54.8	57.8	57.4	54.1	57.4	57.8	55.7	56.5	57.3
	Min	52.3	54.5	56.4	51.5	53.4	55.9	53.5	56.2	56.8	53.6	55.9	57.0	51.0	56.3	56.7
	Max	54.3	53.7	54.0	54.4	53.5	54.4	53.4	54.8	55.7	54.1	54.3	55.4	52.8	55.3	56.7
	Min	49.9	51.4	52.0	49.4	51.0	51.3	51.3	53.9	55.1	51.1	53.5	54.8	51.7	51.5	56.0
10	Max	54.2	54.4	55.1	54.4	54.3	55.4	54.2	54.8	55.2	54.1	54.8	55.3	54.0	54.9	56.6
	Min	53.4	52.9	54.8	53.1	53.9	54.9	53.4	54.7	55.0	53.4	54.4	55.0	53.4	54.6	56.2
11	Max	58.6	56.2	55.0	57.9	56.0	55.2	55.9	54.8	55.1	56.8	54.8	55.0	54.4	54.8	56.2
	Min	54.0	54.2	54.9	53.8	54.6	55.1	53.8	54.6	54.9	54.3	54.5	54.9	54.0	54.5	56.0
12	Max	57.4	57.3	56.8	57.1	57.4	57.0	57.9	56.5	55.9	57.5	56.8	57.3	57.3	56.3	57.2
	Min	54.9	54.8	55.6	54.3	55.0	55.8	54.7	54.9	55.4	54.6	55.4	55.3	55.1	54.8	55.6
13	Max	52.4	51.3	52.1	52.7	51.7	53.0	50.5	51.9	53.2	51.8	51.7	53.0	49.8	52.9	55.2
	Min	46.7	49.0	51.8	46.8	49.3	52.1	48.7	51.3	52.9	48.8	51.2	52.7	49.4	52.6	54.8
	Max	50.8	49.8	50.8	51.2	49.9	51.4	48.6	50.1	51.7	49.3	50.0	51.8	48.0	50.9	54.5
	Min	44.4	46.7	50.1	44.7	47.4	50.6	45.9	49.7	51.6	45.7	49.4	51.3	47.0	50.6	53.7
	Max	53.0	51.4	50.9	53.7	51.4	51.7	50.1	50.3	51.4	51.2	49.6	51.2	47.9	50.4	53.4
	Min	45.5	47.1	50.0	44.9	47.7	50.4	46.9	49.6	51.3	46.7	49.4	51.1	47.0	50.1	53.0
	Max	54.9	53.4	52.7	55.1	53.8	52.8	51.8	52.7	52.2	53.7	51.9	52.1	50.9	50.7	53.0
	Min	50.9	50.4	51.6	50.7	51.0	51.7	49.9	50.1	51.3	50.3	49.9	51.3	48.7	49.9	52.9
	Max	51.4	52.7	52.4	51.0	52.9	52.5	51.9	52.3	52.3	51.8	52.8	52.8	51.6	50.8	52.9
	Min	48.1	49.1	50.4	48.3	51.0	51.4	51.1	50.4	51.6	50.3	51.1	51.9	50.3	50.2	52.3
20	Max	53.3	51.3	51.3	53.8	51.7	51.6	51.0	50.7	52.0	51.9	50.6	51.8	49.1	51.0	53.4
	Min	46.9	48.5	51.4	46.0	48.5	51.1	50.2	48.0	51.5	47.9	50.0	51.4	48.5	50.8	53.2
	Max	54.0	54.2	54.5	54.1	54.3	54.0	52.7	53.8	52.3	53.1	52.9	52.7	52.8	51.0	52.9
	Min	52.8	52.0	51.6	53.5	52.0	51.9	50.8	51.4	51.7	52.1	50.8	51.3	50.2	50.0	52.1
	Max	48.5	51.0	52.7	48.1	51.2	51.4	52.0	50.2	52.0	49.8	52.1	52.3	50.9	50.9	52.1
	Min	46.0	47.4	49.7	45.7	47.4	49.9	46.9	48.9	50.7	46.7	49.2	50.1	47.9	49.2	50.9
24	Max	47.4	47.7	49.9	47.5	47.6	50.0	49.9	48.9	52.1	46.9	49.4	51.6	48.7	51.2	52.4
	Min	[illegible]	45.4	49.1	42.0	45.7	49.6	46.7	45.1	51.2	44.3	48.5	50.4	46.9	50.0	51.9
	Max	47.8	45.9	48.8	48.5	47.2	49.1	48.4	47.9	50.5	46.9	48.1	50.2	46.2	50.1	52.2
	Min	42.0	44.1	47.6	44.7	44.2	48.1	45.8	43.5	49.7	43.1	47.5	49.0	45.5	49.5	51.9
	Max	48.5	47.6	48.3	49.1	48.0	49.0	46.3	47.8	49.5	47.5	47.5	49.0	45.5	48.8	51.5
	Min	[illegible]	45.1	47.9	[illegible]	[illegible]	48.7	44.2	47.0	49.1	44.1	47.1	48.6	45.1	48.3	51.0
	Max	50.6	49.0	48.7	51.3	49.2	49.0	47.8	47.4	48.9	49.1	47.6	48.7	46.9	47.4	50.0
	Min	44.8	[illegible]	47.6	44.1	[illegible]	48.0	44.1	46.7	48.2	44.8	46.8	47.9	44.1	46.8	49.7
	Max	51.1	50.1	48.8	51.5	50.1	50.0	48.7	48.8	49.4	49.9	48.8	49.4	47.1	47.7	49.8
	Min	[illegible]	47.9	48.9	46.5	48.0	49.2	46.8	47.8	48.1	46.9	47.9	48.5	46.4	47.0	49.7
	Max	[illegible]	[illegible]	49.6	46.5	48.9	49.7	47.1	48.9	49.3	47.1	48.8	49.2	47.2	47.9	49.6
	Min	[illegible]	[illegible]	48.9	44.4	[illegible]	48.9	45.9	48.0	49.1	45.9	48.1	49.0	46.5	47.7	49.3
	Max	[illegible]	[illegible]	47.8	41.5	44.0	43.1	45.3	47.2	49.0	43.1	47.3	48.9	44.9	47.8	49.5
	Min	[illegible]	[illegible]	[illegible]	41.2	[illegible]	46.9	[illegible]	46.2	48.6	42.4	45.9	47.9	43.8	47.2	49.3
Monthly range		4.25	2.41	0.96	4.84	2.45	0.78	2.20	1.31	0.52	2.84	0.91	0.70	1.20	0.60	0.56

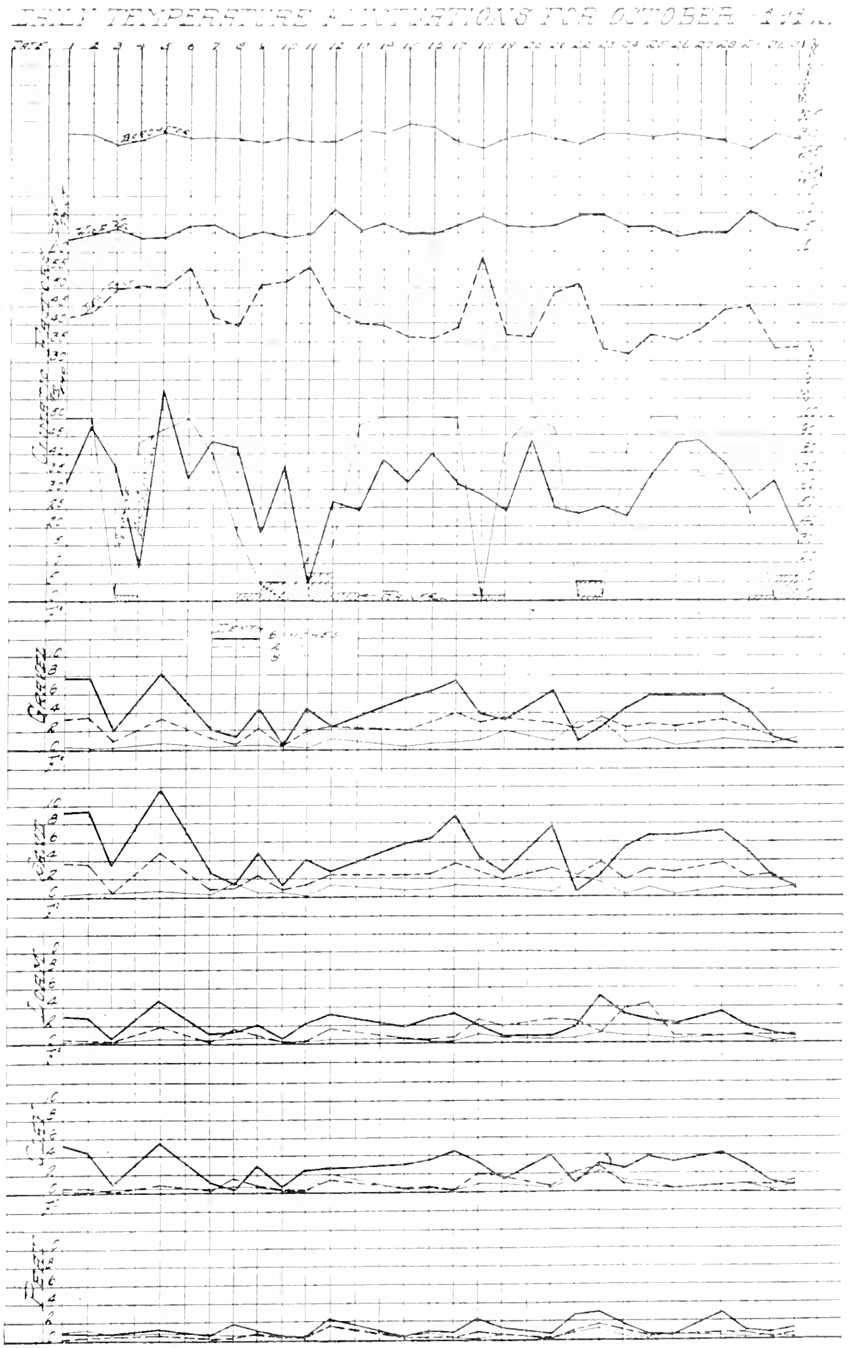

FIG. 26.

MAXIMUM AND MINIMUM TEMPERATURE OF DIFFERENT TYPES OF SOIL, NOVEMBER, 1912.

		Gravel.			Sand.			Loam.			Clay.			Peat.		
		6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	16"	6"	12"	18"
	Max	38.9	41.7	45.4	38.7	42.8	45.1	41.0	45.1	47.9	40.2	44.9	47.1	42.7	46.9	49.5
	Min	37.8	[illegible]	[illegible]	37.2	[illegible]	44.9	39.4	44.0	47.1	39.2	43.8	46.0	41.3	46.1	49.2
	Max	37.3	39.2	43.4	36.3	39.1	43.7	38.2	42.8	46.1	37.8	42.5	45.1	39.9	44.9	48.8
	Min	[illegible]	[illegible]	42.8	[illegible]	38.9	43.1	[illegible]	42.1	45.4	[illegible]	41.9	44.3	39.0	44.0	48.2
	Max	39.8	39.9	42.4	38.9	40.0	42.9	38.2	41.3	44.2	40.2	41.0	43.2	37.4	42.0	46.1
	Min	[illegible]	38.5	41.8	[illegible]	38.8	42.5	37.0	40.5	43.6	36.8	40.8	42.9	37.1	41.4	45.4
	Max	44.5	43.4	43.4	44.9	43.8	43.9	42.1	41.9	44.0	43.1	42.1	43.6	38.9	41.4	45.2
	Min	40.5	[illegible]	[illegible]	40.4	41.9	[illegible]	39.9	41.8	43.5	39.9	41.9	43.2	38.5	40.8	44.5
	Max	48.1	47.5	45.8	48.5	48.7	47.1	46.5	45.1	45.3	47.2	45.8	45.7	43.9	42.1	44.6
	Min	[illegible]	[illegible]	47.4	[illegible]	46.2	45.9	44.6	43.9	44.5	45.5	[illegible]	44.4	42.1	41.6	44.4
	Max	46.5	45.7	47.0	46.3	46.6	47.2	45.7	46.1	46.7	46.5	46.3	46.8	44.4	43.9	45.1
	Min	44.9	[illegible]	47.0	[illegible]	45.7	47.1	44.9	45.9	45.7	45.2	46.2	46.3	44.3	43.0	44.6
	Max	44.1	44.2	46.0	43.8	44.1	46.1	43.3	45.2	46.5	43.7	45.3	46.4	43.0	44.0	45.2
	Min	41.7	[illegible]	45.7	[illegible]	[illegible]	45.5	42.1	44.4	46.0	42.1	44.5	45.9	42.0	43.8	45.1
	Max	42.8	43.2	45.3	42.9	43.8	45.9	42.3	44.7	46.3	42.8	44.6	46.0	42.3	44.1	46.0
	Min	[illegible]	42.9	[illegible]	[illegible]	[illegible]	45.4	41.9	44.1	45.9	41.9	44.1	[illegible]	41.9	43.9	45.9
11	Max	48.0	46.3	45.3	43.8	46.4	45.8	45.2	44.3	45.9	46.4	44.3	45.8	42.8	43.4	46.0
	Min	[illegible]	[illegible]	44.8	43.0	[illegible]	45.0	42.8	43.9	44.9	42.8	43.9	44.7	41.9	42.9	45.2
	Max	[illegible]	49.8	47.9	[illegible]	49.8	48.1	48.9	47.2	46.4	49.9	47.4	46.8	46.7	44.5	45.9
	Min	[illegible]	48.1	[illegible]	48.9	48.1	46.8	47.3	46.2	45.9	47.0	46.4	46.1	45.4	43.9	45.5
	Max	51.3	50.8	49.8	51.3	50.5	49.8	50.4	49.8	48.6	51.0	49.8	49.2	49.1	47.0	46.7
	Min	49.2	50.0	[illegible]	48.7	49.9	[illegible]	[illegible]	48.5	47.1	49.9	48.8	47.9	48.2	45.3	46.2
14	Max	42.9	45.2	48.2	42.0	45.0	41.8	45.0	47.9	48.4	44.3	47.8	48.5	46.3	46.9	46.5
	Min	40.2	[illegible]	[illegible]	[illegible]	42.8	[illegible]	42.4	46.6	48.2	41.9	[illegible]	47.9	44.2	46.9	46.5
	Max	38.4	40.9	45.0	38.1	41.0	45.3	40.1	44.7	47.2	39.4	44.2	46.5	42.5	46.4	47.9
	Min	37.4	[illegible]	44.2	37.6	[illegible]	44.6	39.2	45.7	[illegible]	38.7	43.0	45.3	41.4	45.4	47.9
	Max	36.8	39.1	43.3	35.3	39.3	43.8	38.0	42.5	45.3	37.6	42.1	44.4	40.0	44.6	47.9
	Min	[illegible]	37.9	[illegible]	[illegible]	[illegible]	42.7	36.7	41.4	44.1	36.4	40.8	43.2	38.7	43.2	46.3
	Max	39.7	39.9	42.0	39.1	39.9	42.5	38.0	40.5	43.0	38.8	40.5	42.4	37.8	41.3	44.5
	Min	36.9	38.4	41.8	36.2	38.5	42.1	37.0	40.1	42.8	37.1	40.1	42.2	37.5	40.9	44.2
	Max	41.2	41.0	42.0	41.2	41.0	42.4	39.0	40.6	42.8	39.9	40.6	42.3	37.9	40.5	44.0
	Min	37.5	38.9	41.8	37.2	38.9	42.1	37.4	40.2	42.7	37.8	[illegible]	42.0	37.4	40.2	43.9
	Max	41.4	39.7	42.3	41.5	39.8	42.5	38.7	40.9	42.8	39.3	41.2	42.4	38.3	40.5	43.5
	Min	37.8	[illegible]	41.9	[illegible]	39.0	42.3	37.9	40.8	41.7	37.9	40.9	42.3	38.1	40.3	43.4
	Max	42.3	41.7	42.6	42.5	41.9	42.9	41.0	41.5	42.6	41.0	42.0	42.6	39.9	40.2	42.9
	Min	40.5	41.1	42.0	40.5	41.4	42.4	39.9	40.5	41.9	40.0	40.9	41.6	38.4	39.3	42.3
	Max	39.9	40.4	42.5	39.3	40.9	42.8	39.4	41.8	43.0	39.5	41.8	42.8	39.4	40.6	42.9
	Min	[illegible]	[illegible]	42.2	[illegible]	[illegible]	42.6	38.4	41.3	42.8	38.1	41.1	42.6	38.9	40.4	42.7
	Max	37.2	38.7	41.8	37.1	38.9	42.0	37.8	40.8	42.5	37.4	40.7	42.3	33.2	40.5	43.0
	Min	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	41.9	[illegible]	40.4	42.5	[illegible]	40.3	42.1	38.0	40.5	42.9
	Max	35.9	37.5	40.3	35.5	37.7	40.8	36.0	39.1	41.8	36.2	39.0	41.1	36.7	39.9	42.8
	Min	[illegible]	37.2	[illegible]	35.3	37.4	40.7	[illegible]	[illegible]	41.5	35.9	38.9	40.9	36.6	39.6	42.7
	Max	34.8	36.4	39.2	34.3	36.6	39.9	35.0	38.1	40.7	35.0	36.0	39.9	35.7	38.7	42.0
	Min	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	37.9	40.5	35.0	37.8	[illegible]	35.6	38.5	41.9
	Max	34.9	36.3	39.0	34.8	36.4	39.5	34.9	37.9	40.4	35.0	37.9	39.8	35.6	38.5	41.7
	Min	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	37.8	40.2	34.8	37.6	[illegible]	35.4	38.3	41.5
	Max	35.5	36.8	39.5	35.0	38.0	40.0	35.4	38.2	41.8	35.6	38.1	39.9	35.9	38.6	42.0
	Min	[illegible]	[illegible]	[illegible]	35.0	[illegible]	[illegible]	[illegible]	[illegible]	40.8	[illegible]	37.9	[illegible]	35.8	38.5	41.6
	Max	35.1	36.5	[illegible]	34.8	35.7	39.6	35.0	37.8	40.5	35.4	38.1	39.5	35.5	38.2	41.3
	Min	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	37.3	[illegible]	34.7	37.4	[illegible]	34.8	37.6	40.8
Monthly range		1.85	1.04	0.56	1.97	1.13	0.30	1.03	0.62	0.59	1.50	0.63	0.59	0.73	0.53	0.37

FIG. 27.

The above tables (30-41) with their respective charts, show the following main facts: (1) the daily temperature of all the soils at all three depths fluctuated throughout the year, but in different degree during the different months. The greatest monthly amplitude occurred in June and was followed in order by May, July, August, April, September, October, November, December, January, March and February; (2) sand showed the greatest amplitude for the 6 and 12 inch depths and was followed in order by gravel, clay, loam, and peat. The fluctuation at the 18 inch depth was about the same for all the different soils with a slight difference in favor of the sand and gravel. The amplitude of the 6 inch depth was the greatest in all soils and was followed in order by the 12 and 18 inch depths. The variation between the 6 and 12 inch and the 6 and 18 inch depths were very much greater in the lighter soils than in the heavier soils.

The small soil temperature fluctuation in the winter is very interesting and needs special attention. Theoretically speaking we should expect a greater fluctuation in the winter than in the summer, with the same variation in air temperature, because the specific heat of the soils in summer is close to 0.5, while in the winter it is half this value, because the specific heat of ice is about half of that of water. This smaller amplitude in the winter may be attributed to the following chief causes: (1) in the winter the soil is heated only by conduction while in the summer it is heated by conduction and also by absorption, hence, the temperature is raised to a higher degree in the latter case, and the gradient is higher; (2) the latent heat of ice plays an important part in keeping the magnitude of fluctuations low; and (3) when the soil is covered with a thick layer of snow, its temperature is kept quite steady and varies but slightly.

SEASONAL AND YEARLY AVERAGE AND RANGE OF TEMPERATURE.

On the preceding pages the temperature of the different types of soil has been considered from the standpoint of daily and monthly averages and ranges. It will now be well to present the same data in these forms, by season and year, and thus see what the relations are in these longer periods of time. The data are shown herewith:

TABLE 42.—SEASONAL AND YEARLY AVERAGE TEMPERATURE OF DIFFERENT TYPES OF SOIL.

Season.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
Winter:															
Dec	33.50	34.83	36.87	33.29	34.81	37.16	33.27	35.11	37.10	33.55	35.52	36.98	32.32	34.35	37.13
Jan	26.24	28.14	30.93	24.62	28.27	31.44	26.60	29.68	32.10	26.40	29.27	31.31	25.58	29.68	32.94
Feb......	29.13	29.90	30.84	28.20	29.84	30.88	28.17	29.43	30.75	28.41	29.52	30.39	29.15	29.31	31.27
Ave ...	29.62	30.96	32.88	28.70	30.98	33.16	29.35	31.51	33.42	29.45	31.44	32.90	29.02	31.11	33.78
Spring:															
March...	29.91	30.43	31.04	30.13	30.72	31.42	29.46	30.13	30.72	29.87	30.35	30.83	28.36	30.02	31.13
April.....	41.84	40.70	39.27	41.46	40.04	38.92	39.16	37.47	36.58	40.20	38.44	37.48	34.04	35.48	31.59
May.....	56.07	54.41	52.03	56.11	54.08	52.0	55.07	53.02	50.62	56.00	53.43	51.96	55.61	52.00	50.44
Ave......	42.60	41.85	40.78	42.57	41.61	40.78	41.23	40.21	39.31	42.02	40.74	40.09	39.34	39.17	37.72
Summer:															
June	67.25	65.33	62.61	66.52	64.39	62.08	66.28	63.88	61.00	66.51	63.89	62.24	67.15	64.24	61.64
July.....	72.56	71.11	69.16	71.74	70.20	68.49	72.40	70.55	67.86	72.20	70.15	68.74	73.30	68.56	68.70
Aug.....	68.00	67.18	66.33	67.85	66.85	66.07	67.82	67.00	65.52	68.01	66.92	66.23	68.60	67.22	66.26
Ave......	69.27	67.87	66.03	68.70	67.15	65.55	68.83	67.14	64.79	68.91	66.99	65.74	69.68	66.67	65.53
Autum:															
Sept.	65.49	65.20	65.33	65.08	64.88	65.08	65.76	65.82	65.08	65.56	65.56	65.45	66.37	66.44	66.08
Oct	50.38	51.03	52.25	50.16	51.05	52.37	50.68	51.48	52.69	50.48	51.73	52.61	50.28	51.77	53.89
Nov.....	40.44	41.13	43.32	39.80	41.32	43.67	40.00	42.28	44.12	40.80	42.29	43.70	40.00	42.11	44.68
Ave......	52.07	52.46	53.63	51.68	52.42	53.71	52.15	53.19	53.96	52.28	53.19	53.25	52.55	53.44	54.85
Yearly Ave.	48.39	48.29	48.33	47.91	48.04	48.30	47.89	48.01	47.87	48.18	48.09	48.00	47.65	47.60	47.97

TABLE 43. SEASONAL AND YEARLY RANGE TEMPERATURE OF DIFFERENT TYPES OF SOIL.

Seasons.	Gravel.			Sand.			Loam.			Clay.			Peat.		
	6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"	6"	12"	18"
Winter:															
Dec.	1.31	0.92	0.64	1.09	0.75	0.60	0.66	0.62	0.60	0.69	0.72	0.64	0.60	0.61	0.60
Jan.	0.91	0.89	0.92	1.10	0.95	0.72	0.70	0.50	0.75	0.70	0.52	0.58	0.76	0.45	0.41
Feb.	0.42	0.37	0.41	0.63	0.48	0.46	0.46	0.37	0.42	0.47	0.44	0.32	0.43	0.39	0.36
Ave	0.89	0.73	0.66	0.94	0.73	0.59	0.61	0.50	0.62	0.62	0.56	0.51	0.60	0.48	0.46
Spring:															
Mar.	0.58	0.53	0.41	0.57	0.57	0.51	0.59	0.57	0.58	0.43	0.43	0.84	0.47	0.46	0.43
April	4.93	2.66	0.96	5.41	2.59	0.93	2.47	0.84	0.68	3.25	1.23	0.86	0.76	0.39	0.18
May	6.59	3.18	0.83	7.76	3.28	0.47	2.92	0.78	0.52	4.14	0.97	0.59	1.81	0.98	0.62
Ave	4.03	2.12	0.74	4.59	2.15	0.64	1.99	0.73	0.59	2.61	0.88	0.76	1.01	0.61	0.41
Summer:															
June	7.56	3.32	0.92	8.43	3.32	0.95	3.09	0.87	0.47	4.56	0.90	0.56	1.62	0.48	0.44
July	6.17	3.00	1.04	6.78	3.00	1.03	2.94	1.07	0.63	4.07	1.12	0.78	1.77	0.67	0.59
Aug.	5.22	2.63	1.08	6.59	2.95	1.26	2.56	3.31	0.60	3.47	1.12	0.70	1.34	0.75	0.51
Ave	6.32	2.98	1.01	7.27	3.09	1.08	2.86	1.75	0.57	4.03	1.05	0.68	1.58	0.63	0.51
Autumn:															
Sept.	4.36	1.71	10.0	5.56	2.48	0.97	2.11	0.96	0.56	3.23	1.08	0.71	1.47	0.64	0.49
Oct.	4.25	2.11	0.96	4.84	2.45	0.78	2.20	1.31	0.52	2.84	0.91	0.70	1.20	0.60	0.56
Nov.	1.85	1.04	0.56	1.97	1.13	0.30	1.03	0.62	0.59	1.50	0.63	0.59	0.73	0.53	0.37
Ave	3.49	1.72	0.84	4.12	2.02	0.68	1.78	0.96	0.56	2.52	0.87	0.67	1.13	0.59	0.47
Yearly Range	3.68	1.89	0.81	4.23	2.00	0.75	1.81	0.99	0.59	2.45	0.84	0.66	1.08	0.61	0.46

The chief points brought out in the above tables (42-43) may be summarized thus: (1) the highest seasonal average temperature occurred in the summer followed in order by autumn, spring, and winter; (2) the greatest seasonal amplitude took place also in summer with autumn, spring, and winter coming next in order; (3) the average soil temperature of the autumnal equinox was higher than that of the spring; (4) the yearly average temperature was practically the same for all soils at all three depths; and (5) the yearly range was noticeably different: the sand shows the greatest amplitude and is followed in order by gravel, clay, loam, and peat respectively; the difference between the sand and peat is 3.15 for the 6 inch depth.

COMPARISON BETWEEN MONTHLY AVERAGE AND RANGE OF TEMPERATURE OF THE AIR AND THE SOILS.

It will be interesting now to compare the temperature of the air and of the different soils as to their average and range. The following tables contain these data:

TABLE 44. COMPARISON BETWEEN THE MONTHLY AVERAGE TEMPERATURES OF THE AIR AND OF THE DIFFERENT TYPES OF SOIL.

Soils.	December, 1911.			January, 1912.			February.			March.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
Gravel	33.50	34.83	36.87	26.24	28.14	30.93	29.13	29.90	30.84	29.91	30.43	31.04
Sand	33.29	34.84	37.16	24.62	28.27	31.44	28.20	29.84	30.88	30.13	30.72	31.42
Loam	33.27	35.41	37.40	26.60	29.68	32.10	28.17	29.43	30.75	29.46	30.13	30.72
Clay	33.55	35.52	36.98	26.40	29.27	31.34	28.41	29.52	30.39	29.87	30.35	30.83
Peat	32.32	31.35	37.13	25.58	29.68	32.91	28.15	29.31	31.27	28.36	30.02	31.13
Air		33.36			11.34			17.03			28.38	

Soils.	April.			May.			June.			July.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
Gravel	41.81	40.70	39.27	56.07	54.41	52.03	67.25	65.33	62.61	72.56	71.11	69.16
Sand	41.46	40.04	38.92	56.11	54.08	52.00	66.52	64.39	62.08	71.74	70.20	68.19
Loam	39.16	37.47	36.58	55.07	53.02	50.62	66.28	63.88	61.00	72.40	70.55	67.86
Clay	40.20	38.44	37.48	56.00	53.43	51.96	66.51	63.89	62.24	72.29	70.15	68.74
Peat	34.04	35.48	31.59	55.61	52.00	50.14	67.15	64.21	61.64	73.30	68.56	68.70
Air		50.22			62.00			70.78			75.77	

Soil.	August.			September.			October.			November.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
Gravel	68.00	67.18	66.33	65.40	65.20	65.33	50.38	51.05	52.25	40.44	41.13	43.32
Sand	67.85	66.85	66.07	65.08	64.88	65.08	50.16	51.05	52.37	39.89	41.32	43.67
Loam	67.82	67.00	65.52	65.76	65.82	65.08	50.68	51.48	52.69	40.00	42.28	44.12
Clay	68.01	66.92	66.23	65.56	65.56	65.45	50.18	51.73	52.61	40.80	42.29	43.70
Peat	68.60	67.22	66.26	66.37	66.44	66.08	50.28	51.77	53.80	40.00	42.11	44.68
Air		72.34			68.90			54.55			41.71	

TABLE 45. COMPARISON BETWEEN THE MONTHLY RANGE OF TEMPERATURE OF THE AIR AND OF THE DIFFERENT TYPES OF SOIL.

Soils.	December, 1911.			January, 1912.			February.			March.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
Gravel	1.31	0.92	0.64	0.94	0.89	0.92	0.42	0.37	0.41	0.58	0.53	0.44
Sand	1.09	0.75	0.60	1.10	0.95	0.72	0.63	0.48	0.46	0.57	0.57	0.51
Loam	0.66	0.62	0.69	0.70	0.59	0.75	0.46	0.37	0.42	0.59	0.57	0.58
Clay	0.69	0.72	0.64	0.70	0.52	0.58	0.47	0.41	0.32	0.43	0.43	0.84
Peat	0.63	0.61	0.63	0.76	0.45	0.41	0.43	0.39	0.36	0.47	0.46	0.43
Air		16.77			16.68			21.58			30.49	
Soils.	April.			May.			June.			July.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
Gravel	4.93	2.66	0.96	6.59	3.18	0.83	7.56	3.32	0.92	6.17	3.00	1.04
Sand	5.14	2.59	0.93	7.76	3.28	0.47	8.13	3.32	0.95	6.78	3.00	1.03
Loam	2.47	0.84	0.68	2.92	0.78	0.52	3.09	0.87	0.47	2.91	1.07	0.63
Clay	3.25	1.23	0.85	4.14	0.97	0.59	4.56	0.90	0.56	4.07	1.12	0.78
Peat	0.76	0.39	0.18	1.81	0.98	0.62	1.62	0.48	0.44	1.77	0.67	0.59
Air		31.12			32.48			41.06			36.98	
Soils.	August.			September.			October.			November.		
	6″	12″	18″	6″	12″	18″	6″	12″	18″	6″	12″	18″
Gravel	5.22	2.63	1.08	4.36	1.71	1.03	4.25	2.41	0.96	1.85	1.04	0.56
Sand	6.59	2.95	1.26	5.56	2.48	0.97	4.84	2.45	0.78	1.97	1.13	0.30
Loam	2.56	3.31	0.60	2.11	0.96	0.56	2.20	1.31	0.52	1.03	0.62	0.59
Clay	3.42	1.12	0.70	3.24	1.08	0.71	2.84	0.91	0.70	1.50	0.63	0.59
Peat	1.34	0.75	0.51	1.47	0.64	0.49	1.29	0.69	0.56	0.73	0.53	0.37
Air		34.18			35.45			31.57			19.91	

From table 45 it is seen that during the winter months and up to March the air temperature was below that of the soil temperature of all three depths, during the remainder of the year the reverse was true. The greatest difference between the air and soil temperature occurred in January and the least in December and March. For the remaining months the difference lies between these extremes.

Table 46 shows that the greatest amplitude of the air temperature occurred in June and was followed in order by July, September, August, May, October, April, March, February, Decembar and January, while in the case of the soil the highest amplitude took place also in June with May, July, August, April, September, October, November, December, January, March, and February came in order. It is noticed that the order in both cases was not exactly the same yet almost alike. The range of the air temperature was far greater than that of the soils and is, of course, above it throughout all the months.

EFFECT OF ORGANIC MATTER ON THE TEMPERATURE OF SOILS.

OBJECT AND METHOD OF EXPERIMENTATION.

Organic matter possesses two physical properties which have a remarkable influence upon the soil temperature. These are color and water holding capacity. The soils with the largest amount of organic matter will have the darkest color. Dark or black colored soils, possessing the highest absorbing capacity for heat, would tend to be much warmer than the light colored or white soils, which have less heat absorbing power. On the other hand, the soils with the greatest organic content carry also the largest amount of water, and water possessing such great specific heat and other properties, would tend to keep the temperature of these soils low. It was in order to ascertain to what extent these two physical properties of the organic matter would oppose each other, that the following experiment was undertaken. It consisted of studying the daily temperature of a sandy soil which contained organic matter in the proportions of 1.81, 2.01, 3.32, 5.47, 6.95% and 100% peat. It was prepared by excavating a trench over 3 feet deep and 3 feet wide, placed in it wooden boxes 3x3x3 feet without bottom or top and filled them with a sandy soil. The soil of the upper 21 inches was then taken from each box, added to it the proper amount of organic matter (peat), thoroughly mixed, and then placed back into the box. The percentages of organic matter shown above represent the percentage amounts found by the ignition method, after the respective proportions of peat were added. To the soil showing 1.81% organic matter no peat was added. This is, therefore, the original organic content of the soil as determined by the above method. These various amounts of organic matter imparted to the soil different shades of color, ranging from very light to very dark. The soil with the 1.81% organic matter was covered with a very thin layer of very white quartz sand, thus giving to it a very white color.

The experiment was prepared and was ready for the intended study by October, 1911, but because of an accident to the thermometers, the temperature records were not commenced till the middle of February, 1912.

The temperatures were taken by the electrical resistance thermometers already described, at two different depths, 5 and 18 inches, daily throughout the year, except on Sundays, three times a day at, 7 A. M., 12 M., and 6 P. M.

The tables to follow show the daily, monthly, seasonal, and yearly maximum, minimum and average temperatures, for all the soils at both depths. All the tables with few exceptions are accompanied by diagrams to show their salient facts graphically. On the daily temperature charts are also plotted the meteorological data in order to show more readily any influence that they might have on the soil temperature.

DAILY AND MONTHLY AVERAGE TEMPERATURE.

EFFECT OF ORGANIC MATTER ON THE TEMPERATURE OF SOILS. DAILY AVERAGE, MARCH, 1912.

	Peat.		6.95% Org. Matter.		5.47 Org. Matter.		3.32% Org. Matter.		2.01% Org. Matter.		1.81% Org. Matter.	
	5"	18"	5"	18"	5	18	5"	18"	5"	18"	5"	18"
1	31.95	32.2	32.1	32.15	32.2	32.35	32.15	32.15	32.1	32.2	31.80	32.05
2	31.66	32.3	31.9	32.1	31.93	32.1	32.63	32.63	32.03	32.36	31.5	31.9
4	31.16	32.3	32.1	32.1	23.13	32.1	32.1	32.3	31.1	32.2	30.16	31.7
5	30.4	32.	31.95	31.95	30.7	31.85	31.05	32.0	29.85	32.1	29.5	31.55
6	29.43	32.03	30.4	31.66	29.66	31.76	29.73	31.83	28.93	31.7	29.16	31.0
7	29.13	32.06	30.3	31.9	29.7	32.06	29.8	32.06	28.8	31.5	28.26	30.73
8	29.3	32.13	30.56	31.73	30.06	32.0	30.23	32.2	29.93	31.53	29.0	30.9
9	29.66	31.93	30.9	31.96	30.46	31.76	30.26	32.06	29.33	32.0	29.1	30.76
11	29.96	32.03	30.6	32.03	30.26	31.7	30.23	32.1	30.06	31.43	29.16	31.3
12	30.0	31.9	31.03	31.83	30.3	31.56	30.2	31.83	29.96	30.90	29.03	30.73
13	30.33	31.8	30.76	31.66	30.46	31.73	30.66	31.33	30.3	31.73	29.46	30.93
14	29.46	31.2	29.83	31.0	29.7	30.96	29.8	31.23	29.6	30.8	28.63	30.3
15	29.5	31.4	30.1	31.5	30.1	31.4	30.1	31.6	30.2	31.7	30.1	31.8
16	30.13	31.1	30.5	31.43	30.4	31.23	30.43	31.5	30.3	31.3	29.96	31.03
18	29.9	31.25	30.93	31.46	31.1	31.33	31.1	31.83	31.3	31.83	30.53	31.06
19	30.8	31.33	31.13	31.13	31.15	31.3	31.16	31.66	31.16	31.76	30.6	31.13
20	26.3	27.26	26.53	27.06	26.06	27.56	27.16	27.66	27.1	27.90	26.63	27.2
21	28.1	29.96	29.9	30.43	29.96	30.63	30.4	30.73	30.36	30.63	29.6	30.26
22	29.73	29.96	29.86	30.26	30.13	30.56	30.13	30.73	30.56	30.16	29.86	30.73
23	28.66	31.0	30.73	30.6	31.06	31.33	31.16	31.56	31.4	31.76	30.73	31.43
25	30.3	31.06	30.76	31.4	31.1	31.63	32.15	31.5	31.16	31.5	30.9	31.26
26	30.93	31.36	31.03	31.5	31.8	31.6	31.3	32.	31.93	31.53	30.95	31.06
27	31.66	31.7	31.6	31.73	31.0	32.06	31.73	32.03	31.83	31.93	31.1	31.66
28	31.93	31.1	31.63	31.5	31.9	31.83	31.32	32.2	31.5	31.86	31.03	31.66
29	31.56	32.06	31.6	31.73	31.86	31.6	31.33	32.03	31.93	31.7	31.13	31.4
30	31.5	31.26	30.6	31.23	30.7	31.6	31.23	31.96	31.56	31.16	31.33	31.3
Monthly average	30.06	31.42	30.72	31.36	30.65	31.46	30.84	31.68	30.55	31.44	29.97	31.03

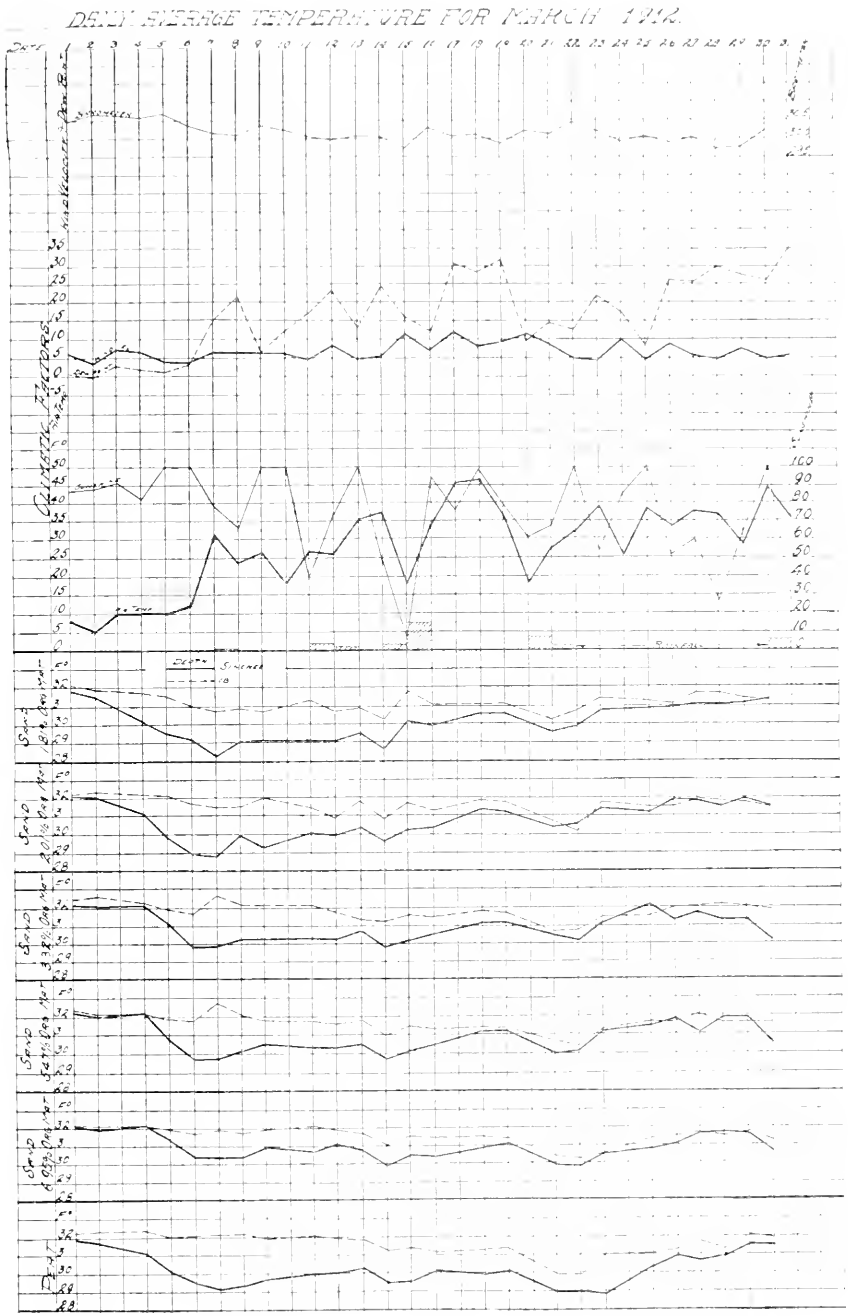

FIG. 28.

TABLE 47. EFFECT OF ORGANIC MATTER ON THE TEMPERATURE OF SOILS. DAILY AVERAGE APRIL, 1912.

Date.	Peat.		6.95% Org. Matter.		5.47% Org. Matter.		3.32% Org. Matter.		2.01% Org. Matter.		1.81% Org. Matter.	
	5"	18"	5"	18"	5"	18"	5"	18"	5"	18"	5"	18"
1	31.86	31.8	32.2	31.56	32.23	32.06	32.03	32.03	32.13	32.23	31.66	31.7
2	31.56	31.7	31.53	31.5	31.56	31.5	31.56	31.63	31.33	31.56	30.8	31.03
3	31.2	31.53	31.33	31.3	31.53	31.5	31.4	31.43	31.23	31.36	31.6	30.86
4	31.13	31.23	31.0	31.06	31.53	31.06	33.76	31.33	34.7	31.43	30.73	30.33
5	31.46	31.8	33.93	31.8	36.86	31.8	40.16	32.0	40.8	31.63	40.13	31.16
6	31.26	31.73	38.7	31.43	41.50	31.76	45.1	31.86	44.63	31.73	42.26	31.26
7	31.36	31.56	33.86	31.36	35.16	31.56	35.0	31.7	35.16	31.6	34.13	31.06
8	31.43	31.56	34.5	31.5	35.83	31.56	37.26	31.73	37.4	31.66	35.36	31.16
9	31.4	31.76	39.7	31.63	41.9	31.6	44.03	31.96	43.3	31.76	42.1	31.7
10	31.23	31.56	44.03	31.53	43.46	31.5	43.30	31.4	43.23	32.36	40.7	33.1
11	32.53	31.53	42.43	31.53	45.86	31.53	48.63	34.93	47.16	34.56	45.03	35.96
12	34.2	31.6	43.03	31.6	45.96	32.9	47.76	38.26	47.0	38.4	45.23	38.3
13	34.7	31.43	42.0	31.4	45.26	38.2	46.8	39.33	46.2	39.06	44.26	38.96
15	38.96	31.5	49.96	40.7	50.76	42.7	50.66	41.66	47.1	41.6	49.13	41.16
16	38.8	31.93	47.96	42.56	49.03	43.7	49.56	43.6	48.86	43.16	46.56	42.7
17	35.96	31.56	41.3	42.9	44.6	43.13	44.26	43.26	43.7	42.56	41.8	41.66
18	35.3	31.86	40.6	41.83	40.9	41.73	40.33	41.36	40.06	40.23	38.6	39.5
19	35.03	31.76	41.63	40.23	42.4	40.16	43.1	40.36	42.3	39.26	39.96	38.33
20	37.66	31.6	41.03	39.46	44.85	40.46	47.4	43.46	45.43	38.9	45.0	38.76
22	41.4	31.9	47.9	41.43	47.83	44.96	47.1	45.1	46.9	45.03	45.5	44.86
23	36.53	31.9	45.1	43.2	45.36	42.93	46.33	42.96	45.53	42.16	43.56	41.36
24	41.6	31.83	51.0	43.83	51.83	44.03	53.1	44.2	52.2	44.3	49.86	44.0
25	39.3	31.6	48.66	44.46	49.36	44.53	51.33	44.8	50.3	44.7	47.76	43.4
26	43.43	31.86	52.5	45.5	53.2	46.26	55.16	46.66	54.8	46.8	53.33	46.23
27	44.33	31.86	52.4	47.2	50.06	47.5	53.43	47.86	53.00	48.03	50.53	47.33
29	37.13	31.96	43.4	44.6	43.4	44.5	43.16	44.16	43.06	43.86	41.66	42.7
30 ...	37.13	31.66	48.2	43.33	49.2	43.33	51.4	43.4	50.6	43.2	47.7	42.2
Monthly average	35.38	31.68	41.84	37.53	43.00	38.12	44.19	37.41	43.64	38.27	42.04	37.82

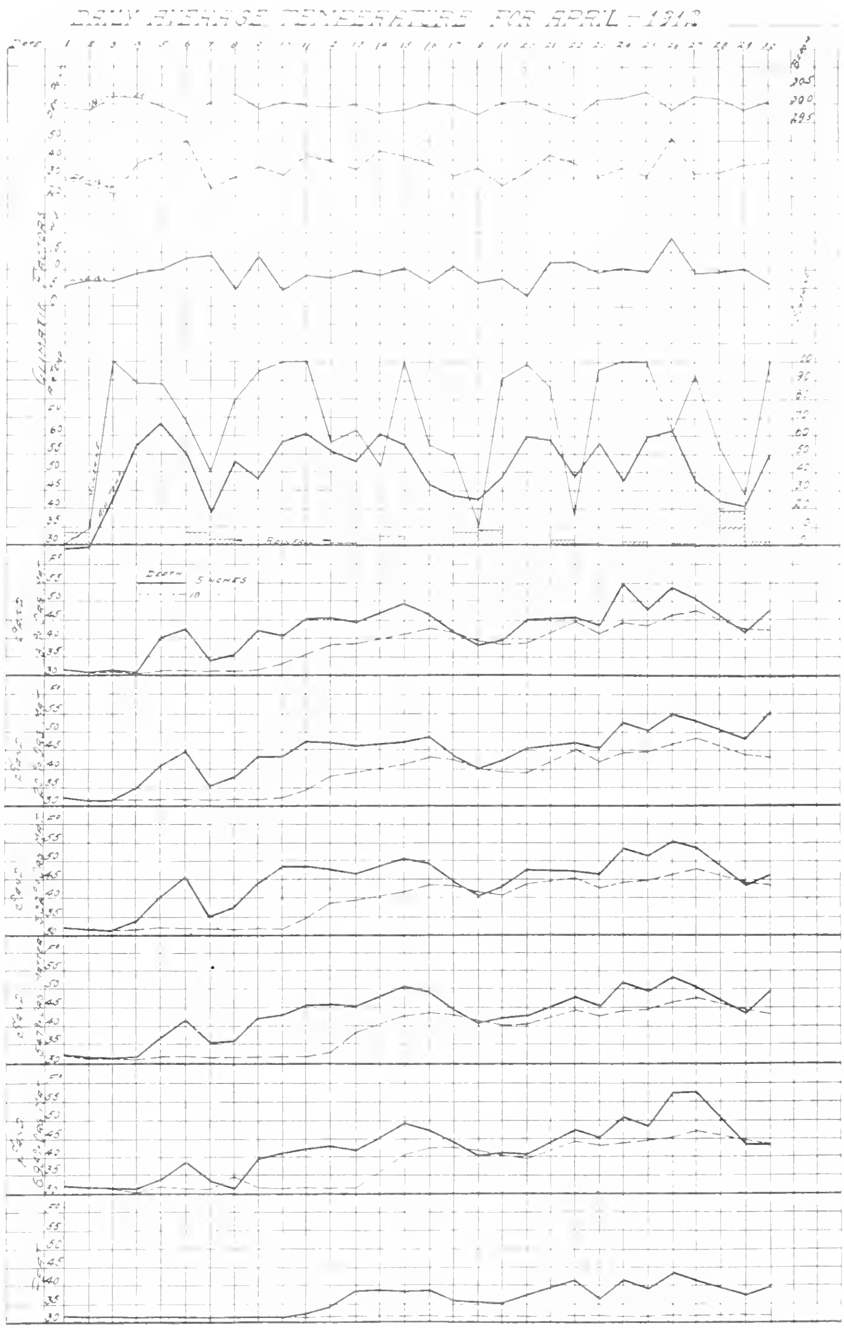

FIG. 29.

TABLE 48. EFFECT OF ORGANIC MATTER ON THE TEMPERATURE OF SOILS. DAILY AVERAGE, MAY, 1912.

Day.	Peat.		6.95% Org. Matter.		5.47% Org. Matter.		3.32% Org. Matter.		2.01% Org. Matter.		1.81% Org. Matter.	
	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″
1	39.7	31.73	47.00	45.4	47.16	45.56	47.5	45.56	47.3	45.43	45.43	44.6
2	41.13	34.96	53.13	45.53	53.93	45.6	55.6	45.73	54.4	46.0	52.3	45.5
3	44.93	34.96	57.53	47.83	58.2	48.3	59.93	48.7	59.2	48.9	56.06	48.5
4	47.26	32.23	59.9	49.83	60.13	50.1	61.46	50.63	60.4	50.76	57.3	50.5
6	51.46	35.86	62.93	52.23	63.1	52.26	64.73	52.7	63.56	52.86	60.33	52.46
7	55.23	39.03	64.86	54.46	65.03	54.76	65.86	55.3	64.66	55.43	61.26	54.8
8	55.13	42.96	59.96	54.56	60.00	54.36	69.63	54.46	59.43	54.43	57.53	53.53
9	51.7	49.56	59.53	54.0	59.76	53.63	60.3	53.73	59.13	53.53	55.9	52.5
10	55.5	50.9	62.13	53.73	62.9	53.8	63.7	53.9	62.76	53.63	58.76	52.76
11	57.16	51.73	58.8	55.0	59.0	55.13	58.86	55.23	58.43	55.13	56.63	54.43
13	49.66	52.7	47.9	49.63	50.06	49.03	50.76	48.96	50.66	48.4	48.23	47.33
14	51.4	51.8	54.53	50.3	55.43	49.93	56.3	50.36	55.46	50.16	51.96	48.66
15	49.96	51.83	48.86	50.76	48.83	50.33	48.73	50.63	48.26	49.63	46.4	48.36
16	49.63	51.1	49.36	49.53	49.46	49.2	49.26	49.1	48.96	48.86	47.56	48.03
17	49.96	50.56	53.56	48.83	54.16	48.73	55.4	48.93	55.0	48.73	52.73	48.03
18	50.6	50.0	51.26	50.1	52.1	49.2	53.1	49.5	52.9	59.0	50.75	47.9
20	52.86	50.6	55.13	51.6	55.56	51.53	55.66	51.56	55.5	51.26	53.9	50.53
21	55.5	51.16	58.9	52.3	59.36	52.23	58.96	52.7	59.43	52.66	58.06	52.5
22	59.53	52.63	65.3	54.5	67.0	54.73	69.56	55.5	69.53	55.83	66.83	55.83
23	62.93	52.53	70.93	57.1	72.36	57.86	71.06	58.73	73.2	59.33	70.0	59.36
24	65.0	54.9	69.93	60.1	69.66	60.43	69.56	60.86	70.6	60.9	68.43	61.03
25	63.63	56.96	70.26	59.66	71.0	59.4	71.73	59.93	70.83	60.2	66.66	59.3
27	66.63	59.43	69.1	62.43	69.33	62.3	68.93	62.6	69.6	62.56	67.46	61.63
28	66.26	59.96	65.7	61.86	66.4	61.66	66.16	61.86	66.36	62.06	65.26	61.86
29	63.33	61.13	59.66	60.66	58.9	60.06	58.43	60.26	58.43	59.93	56.9	59.13
30	69.83	60.1	65.16	57.73	66.53	57.43	68.6	57.83	67.16	57.86	63.83	56.8
31	63.5	59.33	69.96	59.76	70.9	59.76	72.13	60.2	70.76	60.03	66.53	59.1
Monthly average	54.93	49.04	59.66	53.68	60.22	53.60	60.81	53.90	60.45	53.86	57.89	53.15

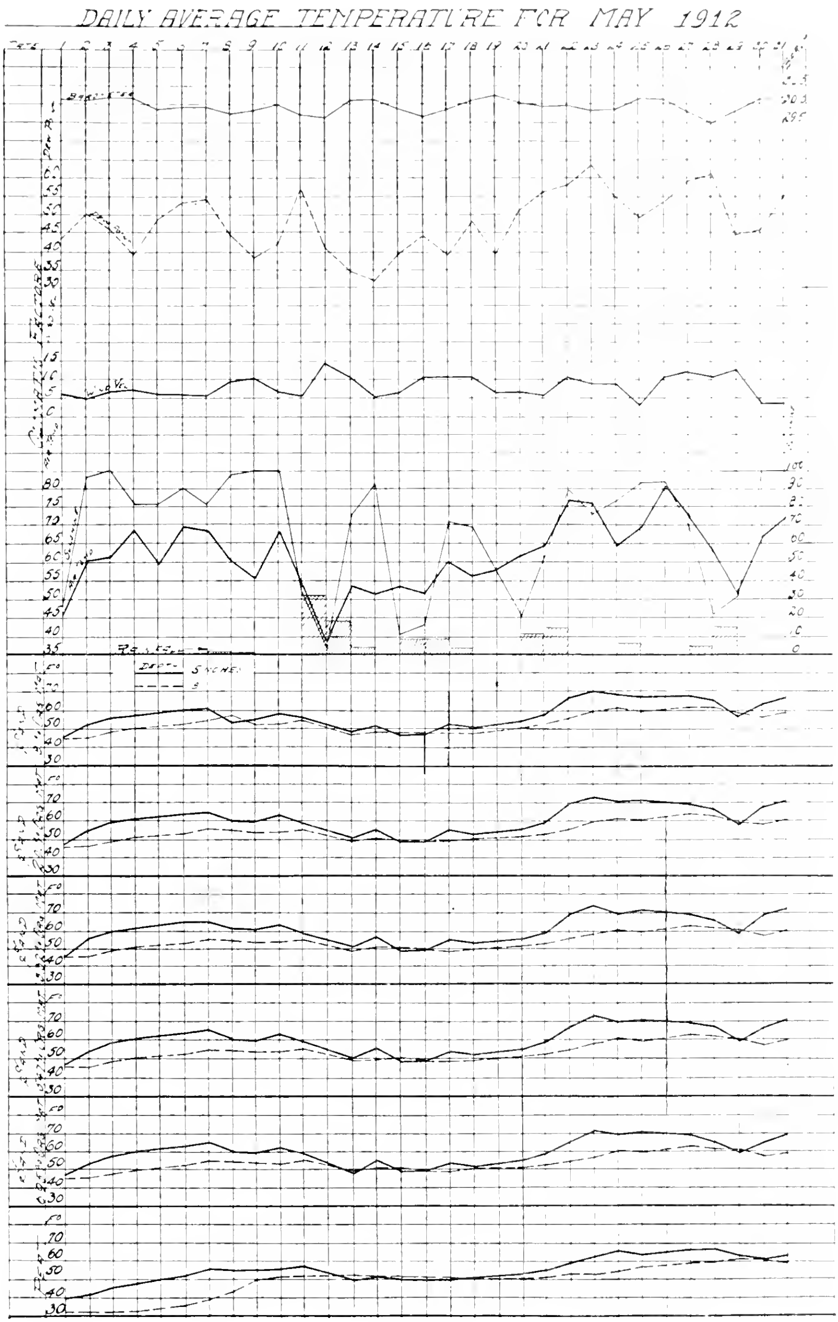

FIG. 30.

TABLE [illegible]. EFFECT OF ORGANIC MATTER ON TEMPERATURE OF SOILS. DAILY AVERAGE JUNE, 1912.

Date.	Peat.		6.95% Org. Matter.		5.47% Org. Matter.		3.32% Org. Matter.		2.01% Org. Matter.		1.81% Org. Matter.	
	5"	18"	5"	18"	5"	18"	5"	18"	5"	18"	5"	18"
1	66.46	60.16	71.96	62.23	73.33	62.16	73.86	62.56	73.63	62.4	69.20	61.46
3	64.96	61.0	69.43	61.56	70.23	61.13	71.36	61.33	70.6	61.13	68.4	60.5
4	65.56	61.4	66.96	62.43	66.66	62.0	67.26	62.2	67.3	62.06	65.1	61.36
5	62.9	61.6	64.66	61.0	64.63	60.33	66.3	60.56	65.8	60.36	62.9	59.4
6	64.9	61.23	69.66	61.76	69.76	61.33	70.66	62.1	69.63	61.93	66.66	61.16
7	63.63	61.3	66.73	61.73	66.9	61.36	67.1	61.13	65.46	60.9	61.96	59.53
8	62.8	61.26	65.96	61.5	66.3	61.16	66.56	61.03	65.16	60.36	61.63	59.0
10	65.36	61.83	69.73	62.76	70.13	62.53	70.23	62.6	69.06	62.03	65.53	60.83
11	64.93	61.3	69.93	63.16	70.6	62.8	70.86	62.83	70.16	62.4	67.36	61.3
12	67.30	61.9	72.23	64.06	72.26	64.03	72.3	64.2	70.93	64.0	69.23	63.73
13	66.53	62.4	70.6	64.26	70.83	63.53	70.86	63.83	70.1	63.6	67.26	62.86
14	65.96	63.0	65.2	64.36	64.83	63.96	64.06	63.9	63.46	63.26	61.93	62.56
15	66.0	62.76	69.86	62.66	70.46	62.55	71.13	62.83	70.7	62.76	68.96	62.5
17	67.46	63.4	70.93	64.36	71.16	64.33	71.83	64.63	71.03	64.1	68.53	63.83
18	65.76	63.26	67.93	64.03	68.53	63.8	68.5	63.83	67.46	63.4	64.5	62.36
19	66.13	63.13	70.40	64.16	70.56	63.76	70.9	63.96	70.16	63.8	67.23	62.73
20	65.96	63.06	69.53	63.86	69.83	63.76	70.23	63.93	69.63	63.66	66.93	62.8
21	66.6	63.23	70.26	64.4	70.36	64.2	70.23	64.43	69.33	64.16	66.36	63.3
22	66.96	63.43	71.73	64.73	72.03	64.63	72.36	64.73	71.23	64.36	68.3	63.43
24	69.33	64.2	73.46	66.66	72.33	66.63	72.2	66.76	71.5	66.53	69.36	65.83
25	69.66	64.93	74.96	66.8	75.26	66.66	75.56	66.9	75.06	67.16	76.03	66.33
26	70.86	65.13	75.5	67.8	75.4	67.73	75.6	68.13	75.06	67.96	73.13	67.56
27	70.7	65.83	74.2	67.83	74.23	67.7	74.3	68.06	73.63	67.76	72.03	67.43
28	70.93	65.93	75.1	67.56	75.0	67.53	75.06	67.8	74.0	66.7	75.93	67.4
29	71.76	65.53	75.8	67.63	76.1	67.63	69.96	67.9	75.16	66.63	77.03	66.6
Monthly average	64.12	62.88	70.51	63.78	70.70	63.89	70.78	64.10	70.24	63.80	67.93	63.02

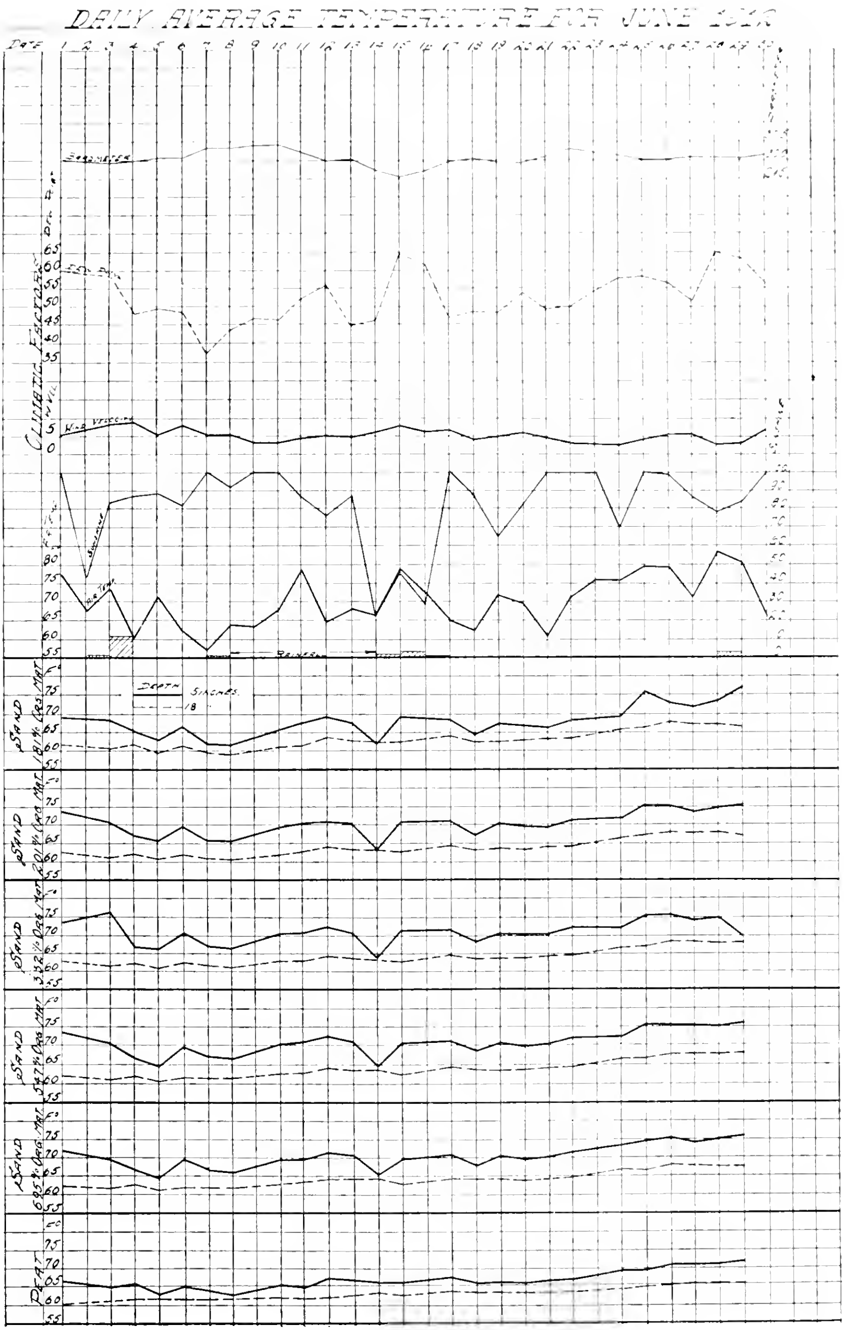
DAILY AVERAGE TEMPERATURE FOR JUNE
Date
Barometer
Climatic Factors
Wind Velocity
Sunshine
Air Temp.
Depth 8 inches
18
Sand
Peat

FIG. 31.

TABLE 5[illegible]. EFFECT OF ORGANIC MATTER ON TEMPERATURE OF SOILS. DAILY AVERAGE. JULY, 1912.

Day.	Peat.		6.95% Org. Matter.		5.47% Org. Matter.		3.32% Org. Matter.		2.01% Org. Matter.		1.81% Org. Matter.	
	5"	18"	5"	18"	5"	18"	5"	18"	5"	18"	5"	18"
1	70.63	67.1	73.63	68.1	73.66	68.13	73.96	68.23	73.23	68.0	71.2	67.33
2	71.33	66.8	75.4	68.2	75.55	68.13	75.36	68.26	75.2	68.3	73.5	68.0
3	73.5	67.4	77.75	69.5	77.46	69.43	77.4	69.7	77.2	69.8	75.63	69.83
4	73.73	67.23	78.13	69.46	77.96	69.4	78.13	69.7	77.96	69.8	76.36	69.7
5	75.66	68.36	78.96	70.9	78.76	71.0	78.73	71.23	78.7	71.53	77.4	71.66
6	76.3	69.7	79.73	71.93	79.13	71.86	78.9	72.26	78.7	72.36	77.3	72.5
8	76.0	70.73	79.03	71.26	79.06	71.16	79.53	71.6	79.3	71.66	77.43	71.6
9	77.0	70.53	81.26	71.83	81.3	71.8	82.33	72.33	82.26	72.66	80.23	72.56
10	78.03	71.36	80.63	73.56	80.03	73.56	79.8	74.1	79.03	73.43	77.5	73.56
11	78.13	72.36	82.23	73.96	81.63	73.76	81.5	74.13	81.2	74.23	79.3	74.0
12	77.2	72.73	79.73	74.1	79.26	73.73	78.86	73.9	78.7	73.76	76.86	73.2
13	75.5	73.06	75.23	73.7	74.86	73.43	74.26	73.10	74.13	73.26	73.0	72.8
15	78.1	72.33	80.16	72.96	80.2	73.03	81.16	74.06	80.86	74.23	78.96	74.1
16	74.2	72.43	74.63	71.73	74.86	71.33	75.7	71.63	75.4	71.4	72.0	70.4
17	75.83	71.83	79.46	71.83	80.1	71.9	80.93	72.5	80.26	72.4	76.93	71.26
18	73.9	71.86	71.76	72.5	71.2	72.23	70.06	72.36	69.6	72.06	68.23	70.9
19	68.66	70.83	68.13	68.13	68.33	67.43	68.63	67.2	67.7	66.5	65.20	65.06
20	68.23	69.7	65.26	67.4	64.96	66.7	64.16	66.83	63.86	66.36	62.53	65.13
22	67.2	66.93	70.06	64.96	71.00	64.86	72.33	65.2	71.7	65.16	70.26	64.7
23	68.56	66.53	69.73	67.54	70.16	66.66	71.0	67.2	70.46	67.13	68.76	66.63
24	70.46	67.2	73.93	67.23	71.36	67.43	75.56	68.06	74.9	68.16	73.56	67.96
25	73.16	67.66	76.73	69.13	77.03	69.4	78.23	70.03	78.1	70.23	76.53	70.23
26	70.63	68.46	72.43	69.33	71.76	69.16	71.93	69.53	71.36	69.3	69.63	68.76
27	69.4	67.46	74.7	68.06	74.3	67.8	74.73	68.2	73.73	68.16	73.7	66.8
29	[illegible]	68.23	70.1	68.53	70.03	68.23	70.23	68.33	70.43	68.3	68.83	67.06
30	68.5	68.1	67.2	67.1	67.23	66.93	67.66	67.16	66.83	67.2	66.5	67.4
31	67.13	67.7	67.26	66.46	66.96	65.76	67.33	65.83	67.66	65.7	69.36	64.86
Monthly average	72.81	69.41	74.93	69.99	74.85	69.77	75.23	70.11	74.55	70.03	72.85	69.58

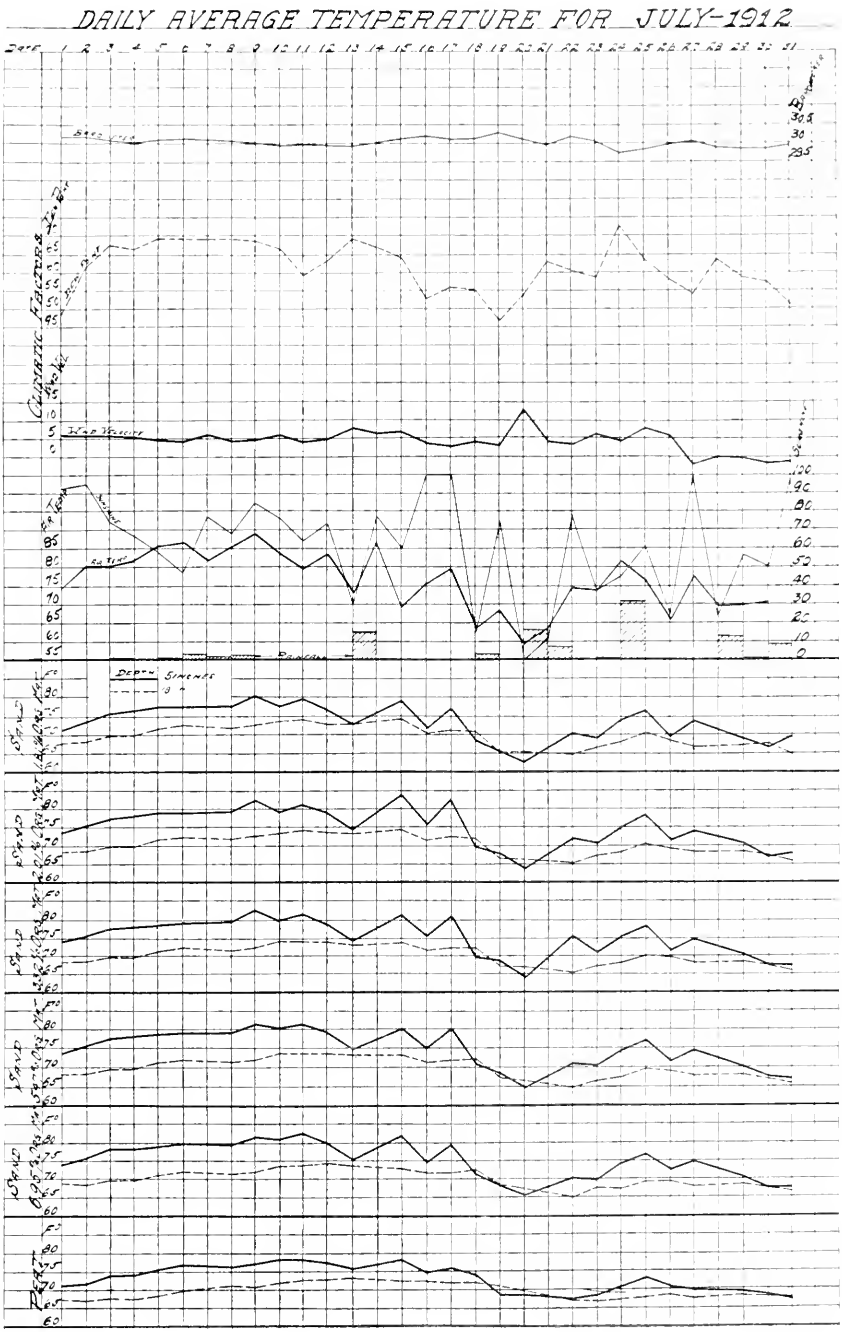
DAILY AVERAGE TEMPERATURE FOR JULY–1912
DATE
CLIMATIC FACTORS
WIND VELOCITY
AIR TEMP.
RAINFALL
SAND
PEAT

FIG. 32.

TABLE 51. EFFECT OF ORGANIC MATTER ON TEMPERATURE OF SOILS, DAILY AVERAGE, AUGUST, 1912.

Date.	Peat.		6.95% Org. Matter.		5.47% Org. Matter.		3.32% Org. Matter.		2.01% Org. Matter.		1.81% Org. Matter.	
	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″
1	66.13	66.8	67.23	65.33	66.43	64.76	67.86	65.13	68.06	65.3	66.23	64.53
2	66.03	66.13	65.9	65.43	63.43	64.86	65.03	65.26	63.36	65.13	63.6	64.43
3	63.2	65.56	62.23	63.63	61.4	62.9	61.4	62.9	61.4	62.56	59.93	61.73
5	65.6	64.13	70.03	64.56	70.16	64.2	70.86	64.6	70.0	64.43	67.13	63.13
6	67.16	64.5	71.3	65.76	71.63	65.83	72.0	66.13	71.33	66.03	68.6	65.13
7	68.6	64.96	75.53	67.1	72.1	67.13	72.46	67.46	71.9	67.26	69.76	66.53
8	69.56	65.4	73.13	67.36	73.53	67.4	73.73	67.66	73.06	67.33	71.3	66.9
9	70.23	65.66	71.73	67.76	71.86	67.3	71.96	67.96	71.76	68.06	70.56	67.63
10	69.0	66.56	69.86	67.0	70.0	66.86	69.93	66.96	69.83	66.8	68.73	66.5
12	68.6	65.93	70.86	65.53	71.0	65.63	72.53	65.96	72.46	66.06	71.23	66.0
13	71.5	66.0	75.36	67.23	75.76	67.33	77.69	68.36	77.56	68.83	76.10	69.06
14	72.53	66.8	76.5	68.96	72.96	69.0	77.8	69.83	77.23	70.23	74.86	70.1
15	70.8	67.5	72.16	69.1	71.8	68.93	71.7	69.3	70.83	69.16	68.7	68.56
16	69.4	67.53	71.96	68.15	72.26	67.66	72.46	67.83	71.13	67.70	68.43	66.3
17	68.8	67.3	68.93	67.9	68.8	67.46	68.7	67.56	68.13	67.13	66.56	65.96
19	70.83	67.06	71.46	68.6	71.43	68.6	70.83	68.96	70.6	68.8	69.66	68.43
20	70.56	67.2	72.56	67.8	73.1	67.8	73.93	68.1	73.86	68.1	72.5	67.83
21	71.1	67.86	72.5	68.5	73.23	68.23	74.3	68.96	71.23	69.16	72.73	68.86
22	70.33	68.43	70.16	68.7	70.7	68.76	71.76	69.4	71.56	69.36	69.73	68.8
23	67.23	67.86	66.73	66.96	66.8	66.4	67.16	67.2	66.9	66.86	64.7	65.86
24	65.76	66.9	72.56	65.26	70.4	65.13	68.13	65.6	70.93	65.23	68.23	64.4
26	73.9	66.83	78.9	70.63	78.93	70.93	78.63	71.43	78.43	71.83	76.63	71.73
27	71.63	68.86	73.83	70.83	73.43	70.73	72.93	70.7	72.0	70.36	69.56	69.65
28	68.0	68.2	65.06	68.1	64.86	68.2	64.06	67.86	63.93	67.2	64.9	66.06
29	66.3	67.46	65.96	65.9	66.13	65.63	69.5	65.56	65.96	65.06	64.7	64.23
30	63.26	65.53	60.8	63.53	60.5	63.06	60.73	63.8	60.83	62.5	60.2	61.83
31	65.23	64.53	70.6	62.56	71.63	62.73	72.96	63.43	72.43	63.6	71.23	63.36
Monthly average	68.55	66.55	70.52	66.96	70.15	66.78	70.77	67.19	70.36	67.04	68.52	66.40

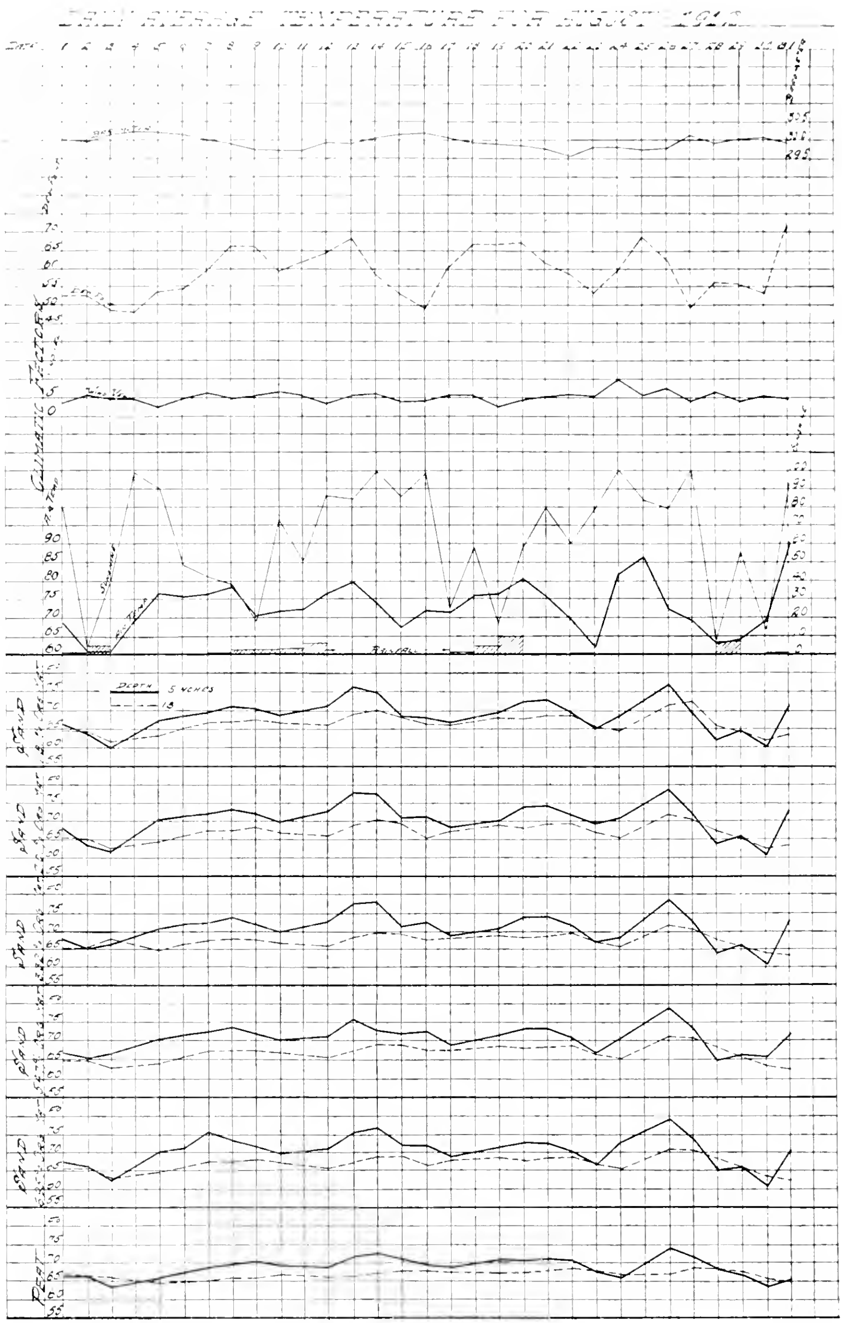

FIG. 33.

TABLE 52.—EFFECT OF ORGANIC MATTER ON TEMPERATURE OF SOILS. DAILY AVERAGE, SEPTEMBER, 1912.

Date.	Peat.		6.95% Org. Matter.		5.47% Org. Matter.		3.32% Org. Matter.		2.01% Org. Matter.		1.81% Org. Matter	
	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″
2	73.17	66.03	78.60	69.43	79.43	69.90	80.03	70.53	79.37	70.83	77.23	70.97
3	73.70	66.90	77.50	70.20	77.83	70.53	77.80	70.87	76.87	71.00	75.00	70.80
4	73.70	68.77	75.70	71.13	75.87	71.17	75.67	71.27	75.07	71.23	73.43	70.77
5	73.97	69.33	77.00	71.00	77.57	71.17	77.67	71.57	77.03	71.43	74.97	71.10
6	73.87	69.60	77.37	71.03	77.97	71.10	78.10	71.53	77.87	71.47	76.80	71.27
7	74.37	70.00	77.93	71.70	78.50	71.83	78.30	71.83	77.57	72.00	76.27	72.07
9	73.67	69.57	78.43	71.33	79.30	71.77	79.53	72.03	78.60	71.93	76.13	71.50
10	71.33	70.27	78.63	72.57	79.27	73.10	79.33	72.90	78.67	73.07	76.50	72.53
11	73.00	70.93	73.70	72.83	73.53	72.77	72.17	73.00	72.77	72.63	71.80	72.03
12	68.63	70.47	66.77	68.97	67.20	68.67	67.30	68.60	67.57	68.40	66.70	67.33
13	67.17	69.37	66.83	67.27	67.60	67.17	68.57	67.37	69.07	67.50	67.23	66.63
14	67.00	67.90	66.87	66.50	67.20	66.50	67.67	67.07	67.60	67.03	66.50	66.37
16	65.80	66.83	65.27	65.47	65.63	65.33	65.30	65.33	65.10	65.03	63.97	64.33
17	63.93	66.40	61.27	64.83	61.03	64.53	60.63	64.47	60.77	64.17	59.97	63.40
18	63.73	65.37	64.23	63.53	64.53	63.53	64.70	63.63	64.53	63.53	63.67	62.90
19	61.33	64.90	58.13	62.97	58.03	62.83	58.17	62.60	58.27	62.27	57.23	61.00
20	59.90	63.47	59.97	61.13	60.07	60.77	60.77	60.97	60.37	60.67	59.27	57.90
21	61.50	62.87	62.83	61.57	63.47	61.63	64.60	62.10	64.83	61.90	63.70	61.53
23	59.60	62.73	60.00	61.00	60.70	60.83	61.17	61.07	61.00	60.77	59.50	59.87
24	59.30	61.13	59.53	60.47	60.23	59.93	60.37	60.17	60.50	60.03	59.43	59.27
25	61.43	61.23	63.90	60.77	64.90	60.97	66.03	61.50	65.43	61.40	65.70	61.00
26	61.30	61.70	59.23	62.03	58.70	61.93	59.03	62.33	59.90	62.40	58.90	61.80
27	55.03	62.07	53.57	58.53	53.73	58.33	54.33	58.37	53.80	57.83	52.27	56.13
28	54.10	60.06	51.46	57.30	51.03	57.03	50.36	56.96	50.46	56.93	49.73	55.40
30	51.53	57.16	50.36	51.66	50.36	51.33	50.56	53.83	51.03	53.26	49.96	53.23
Monthly average	65.80	65.81	66.61	65.53	66.96	65.50	67.15	65.68	66.96	65.57	65.69	64.93

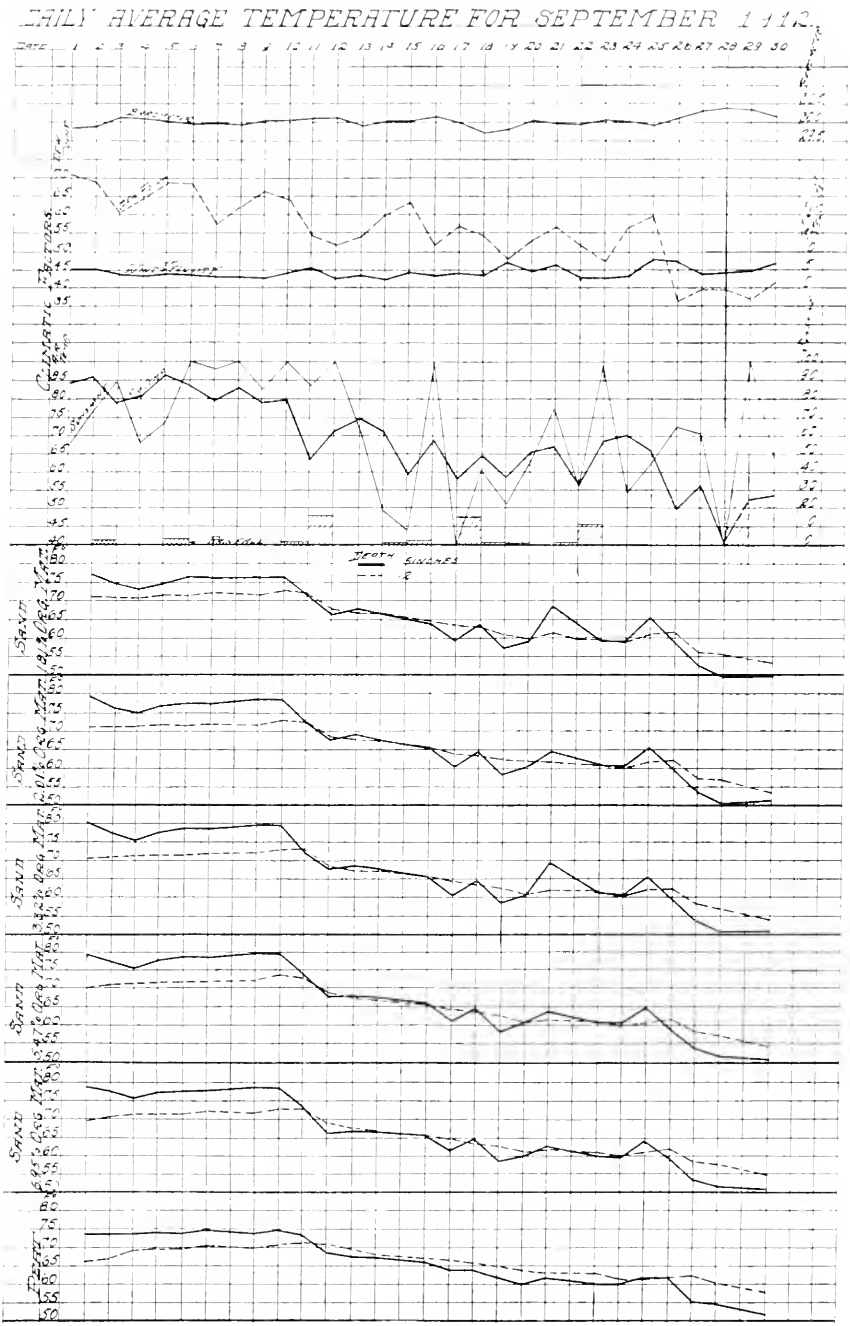
DAILY AVERAGE TEMPERATURE FOR SEPTEMBER 1912.
CLIMATIC FACTORS
SAND 1.81% ORG. MAT.
SAND 2.01% ORG. MAT.
SAND 3.32% ORG. MAT.
SAND 5.47% ORG. MAT.
SAND 6.95% ORG. MAT.
PEAT

FIG. 34.

TABLE 53. EFFECT OF ORGANIC MATTER ON TEMPERATURE OF SOILS. DAILY AVERAGE, OCTOBER, 1912.

Date.	Peat.		6.95% Org. Matter.		5.47% Org. Matter.		3.32% Org. Matter.		2.01% Org. Matter.		1.81% Org. Matter.	
	5"	18"	5"	18"	5"	18"	5"	18"	5"	18"	5"	18"
1	51.90	57.26	53.76	54.40	54.20	54.23	54.56	54.30	54.43	54.00	53.23	53.03
2	51.76	56.23	54.16	54.96	54.76	54.53	55.33	54.90	55.36	54.50	54.03	53.43
3	52.20	56.23	52.60	55.50	52.76	55.20	53.06	55.30	53.00	54.96	52.13	54.13
4	54.9	55.7	55.95	55.40	55.95	55.25	55.95	55.85	55.60	55.80	54.65	55.20
5	54.66	55.86	57.56	56.23	58.03	56.20	56.03	56.13	58.40	55.90	57.46	55.83
7	58.26	56.23	60.03	58.73	59.66	58.90	59.50	59.40	59.69	59.43	58.66	59.06
8	52.86	56.60	51.03	57.03	50.06	57.16	49.46	55.63	49.50	54.96	48.33	57.10
9	51.83	55.40	52.36	54.00	52.76	53.70	33.00	53.73	52.56	53.26	51.53	52.46
10	54.23	55.60	54.07	55.17	54.07	55.07	54.10	55.07	53.90	54.73	53.10	54.27
11	55.47	55.53	57.00	55.13	57.10	55.20	57.30	55.57	57.07	55.30	55.90	55.07
12	56.83	55.63	55.20	56.77	54.50	56.57	53.63	56.63	53.63	56.43	53.03	55.90
14	48.55	54.75	50.40	51.85	51.75	51.65	52.35	51.7	52.35	51.25	51.85	50.60
15	48.70	53.90	48.63	51.87	49.43	51.10	48.93	51.50	48.83	51.00	47.87	49.97
16	46.57	52.07	46.83	50.60	47.23	50.20	47.40	50.10	47.23	49.87	45.70	48.57
17	47.10	52.17	49.87	50.53	51.30	50.53	51.33	50.70	50.87	50.30	49.37	49.13
18	50.47	51.50	54.47	52.07	55.20	52.17	56.60	52.57	55.67	52.50	54.67	52.17
19	50.37	51.50	48.83	51.60	49.27	51.97	48.77	52.27	48.73	52.07	48.30	51.50
21	48.87	52.60	51.11	51.30	51.70	51.00	52.10	51.13	51.57	50.67	50.73	49.72
22	52.83	51.77	53.07	54.93	55.10	53.30	54.77	54.00	54.83	53.47	54.37	53.37
23	48.17	51.37	45.10	50.90	44.13	50.20	43.10	50.00	43.40	49.17	43.20	48.67
24	45.83	52.43	44.10	49.83	43.70	49.13	43.03	48.73	43.00	48.03	42.60	46.77
25	45.40	51.47	44.70	48.50	44.77	47.60	45.13	47.53	45.33	47.07	44.60	46.03
26	45.27	50.77	46.13	48.40	46.00	48.10	46.10	48.03	46.03	47.73	45.13	46.83
28	45.63	49.37	48.27	48.47	48.10	48.23	48.77	48.20	49.10	47.90	47.53	46.97
29	47.80	49.57	50.17	49.83	50.57	49.73	51.23	50.07	51.30	49.93	50.30	49.40
30	47.10	49.47	44.43	49.40	44.10	49.23	43.37	49.20	43.50	48.67	42.73	48.07
31	43.37	49.50	39.30	47.50	39.17	47.00	38.49	46.77	38.27	45.67	37.40	44.03
Monthly average	50.26	53.37	50.70	52.63	50.93	52.34	50.11	52.41	50.85	52.04	49.93	51.37

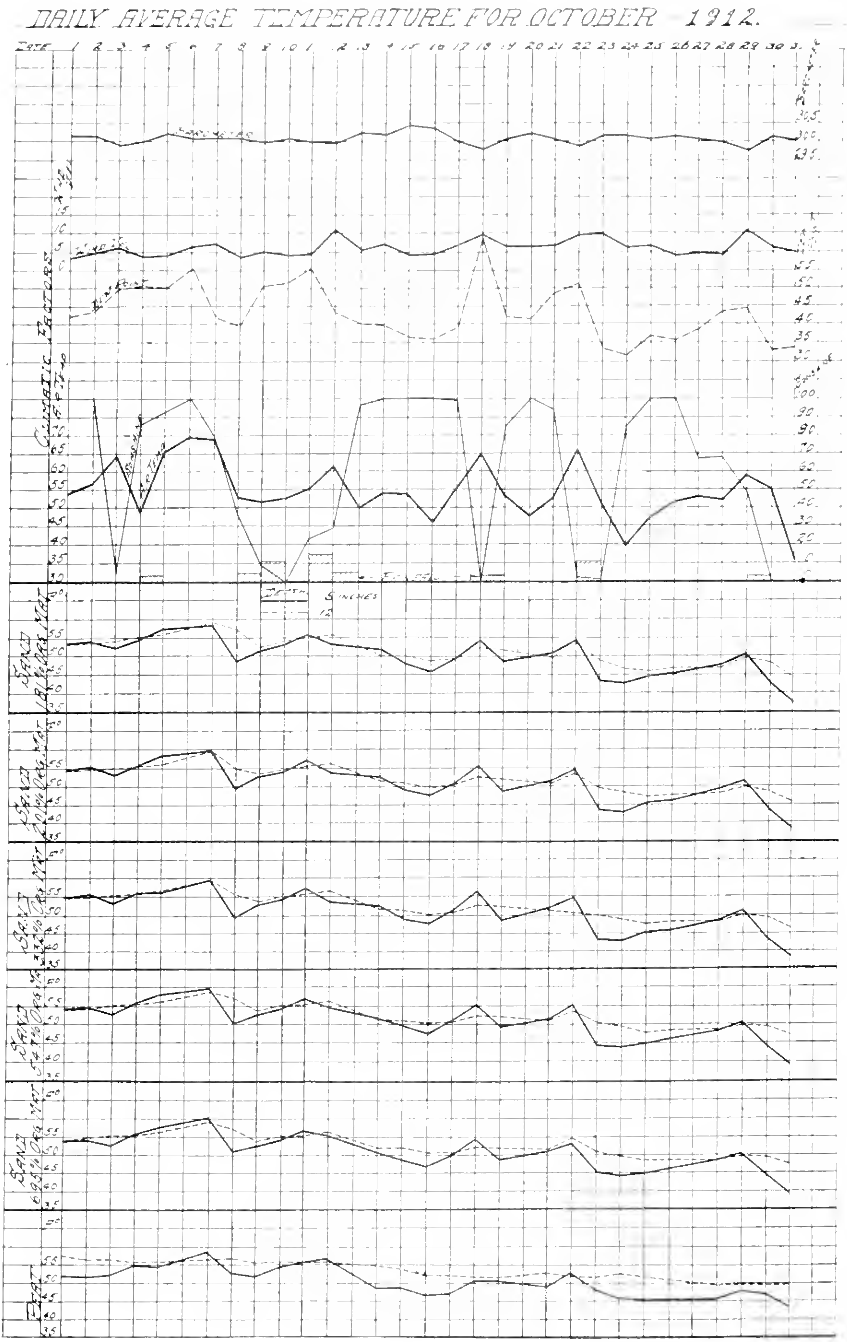
DAILY AVERAGE TEMPERATURE FOR OCTOBER 1912.
CLIMATIC FACTORS
BAROMETER
WIND
DEW POINT
SUNSHINE
MAXIMUM
DEPTH
SAND
PEAT

FIG. 35.

TABLE 51. EFFECT OF ORGANIC MATTER ON TEMPERATURE OF SOIL. DAILY AVERAGE, NOVEMBER, 1912.

Date.	Peat.		6.95% Org. Matter.		5.47% Org. Matter.		3.32% Org. Matter.		2.01% Org. Matter.		1.81% Org. Matter.	
	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″
1	40.16	48.86	36.13	45.03	35.83	44.26	35.03	43.76	35.10	43.16	34.69	41.60
2	38.30	47.36	35.40	42.86	34.90	42.43	34.00	42.10	33.96	41.23	33.23	39.60
4	36.90	44.73	37.90	42.36	38.00	42.03	37.90	41.86	38.26	41.23	37.56	39.96
5	40.10	44.23	43.73	43.70	41.30	43.76	45.20	43.90	44.90	43.60	44.23	42.96
6	45.86	44.50	48.80	46.56	49.20	46.90	49.03	47.40	49.16	47.36	48.60	47.16
7	45.76	45.43	45.73	47.46	45.60	47.46	44.53	47.70	44.45	47.40	43.46	46.97
8	42.66	46.06	42.20	45.93	42.16	45.43	42.03	45.20	42.06	44.76	41.10	43.83
9	42.40	46.26	41.93	45.50	41.96	45.36	41.93	45.20	41.80	44.90	40.90	43.96
10	4[illegible].53	45.33	46.96	45.33	47.36	45.56	48.46	45.60	48.13	45.40	47.36	44.53
12	48.63	45.96	51.30	48.53	51.56	48.40	52.20	48.86	52.00	48.80	51.30	48.70
13	50.53	47.66	50.53	50.23	50.06	50.53	49.36	50.83	49.40	50.70	48.70	50.46
14	43.90	48.20	38.76	47.33	38.10	46.93	36.96	46.56	37.06	46.16	36.23	44.60
15	40.46	47.90	36.86	44.50	36.20	44.03	35.56	43.70	35.00	42.80	33.73	41.40
16	38.20	46.26	34.80	42.73	34.10	42.10	33.20	41.83	33.00	40.93	31.63	39.26
17	37.63	43.50	37.60	41.96	37.66	41.89	36.90	41.60	37.20	40.90	36.20	39.63
19	38.13	43.26	39.46	42.06	39.73	41.86	39.86	42.03	39.76	41.50	39.06	40.53
20	38.60	43.06	39.13	42.36	39.43	42.26	40.13	42.10	39.90	41.63	38.76	40.66
21	40.00	42.23	42.23	42.66	43.06	42.53	43.76	42.93	43.86	42.60	43.26	42.26
22	39.13	42.90	37.89	42.93	37.86	42.76	38.30	42.43	38.13	41.70	37.40	49.26
25	36.87	42.50	34.73	40.50	34.57	40.30	33.73	39.57	33.67	38.83	32.70	37.67
26	36.03	41.73	34.07	39.43	34.07	39.27	33.27	38.97	33.00	38.20	32.00	37.17
27	35.70	41.33	34.20	39.07	34.10	39.03	33.80	38.63	33.17	38.07	32.20	36.80
29	36.00	41.65	34.75	39.50	34.55	39.15	34.00	39.05	33.80	38.40	32.95	37.30
30	35.17	40.90	34.17	38.97	33.77	38.77	33.17	38.53	33.07	38.00	32.03	36.73
Monthly average	40.45	44.67	39.97	43.63	39.92	43.46	39.68	43.34	39.58	42.80	38.72	41.60

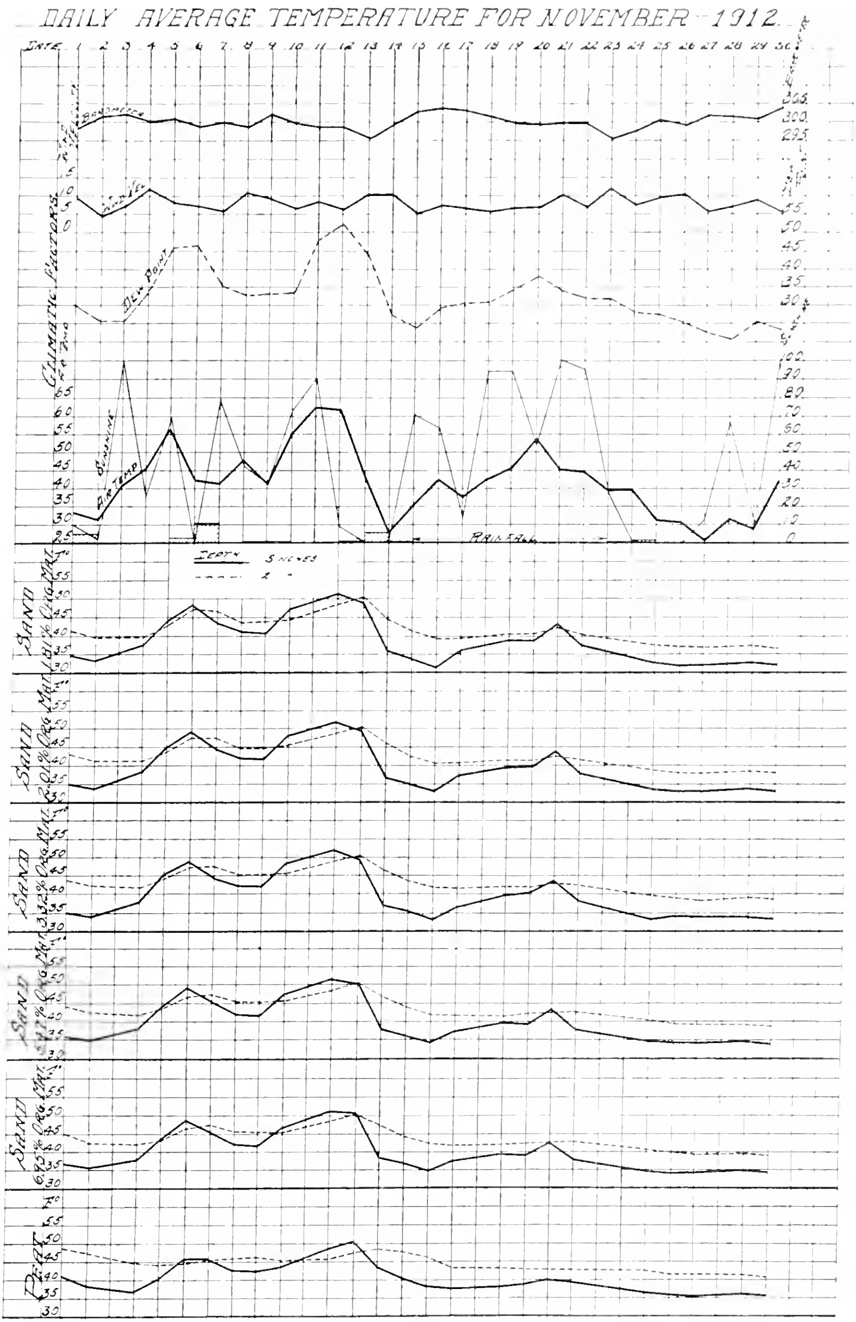
DAILY AVERAGE TEMPERATURE FOR NOVEMBER 1912.
DATE
BAROMETER
WIND VEL
DEW POINT
CLIMATIC FACTORS
SUNSHINE
AIR TEMP
RAINFALL
DEPTH 5 INCHES
2
SAND 1.81% ORG. MAT.
SAND 2.01% ORG. MAT.
SAND 3.32% ORG. MAT.
SAND 6.95% ORG. MAT.
PEAT

FIG. 36.

TABLE 55. EFFECT OF ORGANIC MATTER ON TEMPERATURE OF SOILS. DAILY AVERAGE, DECEMBER, 1912.

Date.	Peat.		6.95% Org. Matter.		5.47% Org. Matter.		3.32% Org. Matter.		2.01% Org. Matter.		1.81% Org. Matter.	
	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″
2	39.70	40.20	43.53	41.27	43.80	41.67	47.00	42.43	47.07	42.40	43.00	42.20
3	38.00	40.87	36.57	41.50	36.27	41.20	35.30	40.90	35.23	40.20	34.23	38.97
4	36.93	40.63	38.40	40.00	38.53	39.83	38.40	39.90	38.30	39.60	37.47	38.77
5	37.13	40.47	38.83	40.07	39.37	40.00	39.80	39.93	39.63	39.47	38.70	38.57
6	40.80	40.97	40.03	42.27	39.53	42.47	38.37	42.70	38.27	42.50	37.53	41.87
7	37.23	41.13	35.13	40.40	34.60	40.07	33.60	39.77	33.53	39.10	32.60	37.90
9	34.87	40.13	33.10	38.37	32.70	38.10	31.47	37.83	31.20	37.07	30.00	35.70
10	34.13	39.63	32.43	37.50	31.90	37.17	31.33	37.03	31.13	36.33	30.27	35.10
11	33.87	39.20	32.53	37.37	32.10	37.03	31.27	37.00	31.17	36.23	30.20	35.07
12	33.37	38.63	30.97	36.87	29.17	36.43	27.00	36.23	26.53	35.37	25.00	33.90
13	32.70	38.03	30.10	36.03	29.37	35.63	28.47	35.30	28.50	34.53	27.37	33.17
14	32.37	37.40	30.13	35.57	29.50	35.30	28.83	34.93	28.83	34.30	27.87	32.77
16	32.10	36.73	31.33	35.10	31.40	34.90	31.37	34.93	31.23	34.33	30.80	33.17
17	32.37	36.83	31.57	35.10	31.77	35.10	31.87	35.20	32.23	34.90	32.50	33.87
18	33.03	37.33	32.30	36.10	32.50	35.83	32.50	35.93	33.23	35.77	32.47	34.97
19	33.10	37.20	32.33	36.07	32.57	36.00	32.97	36.27	32.97	35.87	32.00	35.00
20	33.00	37.10	32.27	35.93	32.40	35.80	32.70	36.03	32.53	35.57	31.37	34.67
21	33.07	37.00	32.57	35.97	32.80	36.00	32.80	36.23	32.73	35.77	31.60	34.70
23	32.40	36.33	31.80	35.43	31.50	35.37	31.27	35.43	30.63	35.00	29.53	33.67
24	32.00	35.93	31.23	35.07	31.23	34.97	31.10	34.93	30.87	34.43	29.97	33.20
26	32.43	36.30	31.37	35.33	31.13	35.20	30.87	35.17	30.53	34.83	29.33	33.47
27	32.80	36.63	32.23	35.83	32.37	35.67	32.23	35.73	32.17	35.17	31.23	34.20
28	32.50	36.30	31.35	35.45	30.85	35.35	30.50	35.35	29.65	34.55	28.30	33.55
30	32.80	36.23	31.93	35.43	32.17	35.27	32.20	35.20	32.03	34.83	31.20	33.67
31	31.90	35.80	31.60	34.83	31.73	34.70	31.60	34.77	31.53	34.40	30.83	33.27
Monthly average	34.18	38.13	33.43	37.17	33.25	37.00	32.99	37.00	32.87	36.50	31.81	35.42

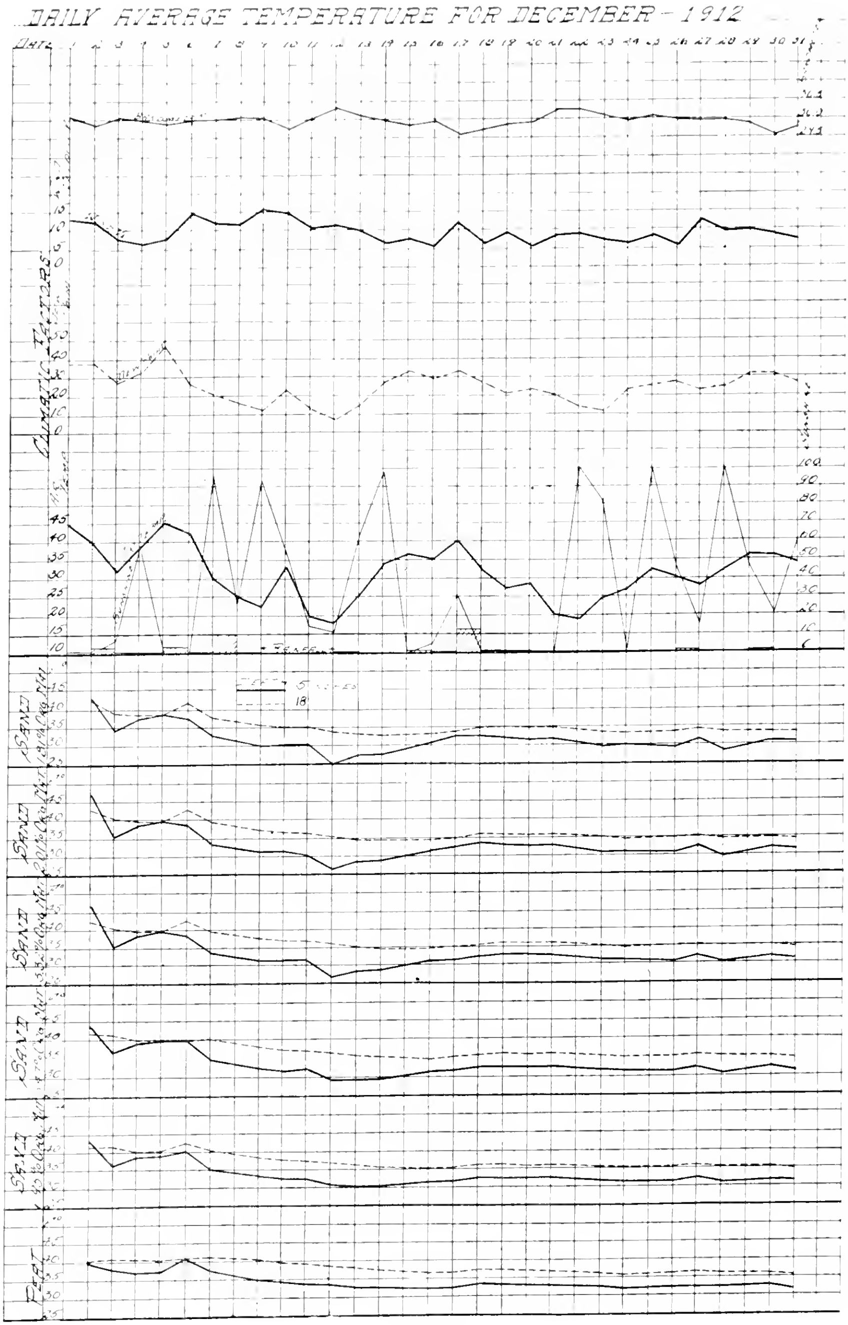
DAILY AVERAGE TEMPERATURE FOR DECEMBER - 1912
DATE
CLIMATIC FACTORS
SAND
PEAT

FIG. 37.

TABLE 56. EFFECT OF ORGANIC MATTER ON SOIL TEMPERATURE. DAILY AVERAGE, JANUARY, 1913.

Date.	Peat.		6.95% of Peat.		5.47% of Peat.		3.32% of Peat.		2.01% of Peat.		1.81% of Peat.	
	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″
1	31.77	35.63	31.50	34.77	31.60	34.70	31.43	34.80	31.30	34.13	30.57	33.20
2	31.80	35.53	31.43	34.89	31.70	34.80	31.40	34.80	31.47	34.20	30.73	33.27
3	32.33	35.90	31.97	35.20	32.13	35.17	32.10	35.23	32.00	34.77	31.03	33.77
4	32.37	35.90	32.03	35.10	31.97	35.07	31.90	35.17	31.73	34.83	31.10	33.80
6	31.70	35.67	31.47	34.77	31.47	34.57	31.53	34.53	31.43	33.73	30.60	32.87
7	32.67	36.33	32.07	35.37	32.00	35.37	31.80	35.33	31.83	34.90	30.80	33.90
8	32.80	36.40	32.60	35.70	32.30	35.30	32.30	35.30	32.10	34.90	31.10	34.00
9	31.85	35.30	31.35	34.55	31.15	34.50	31.05	34.60	31.00	34.10	29.90	33.15
10	32.17	35.83	31.70	34.97	31.47	34.83	31.33	34.80	31.30	34.30	30.30	33.40
11	32.07	35.67	31.93	34.80	32.03	34.60	32.03	34.63	31.77	34.23	31.07	33.23
13	32.40	35.80	32.40	35.00	32.37	35.03	32.43	34.90	32.30	34.80	29.50	33.73
14	32.23	35.83	32.37	35.00	32.07	34.97	32.20	35.03	31.90	34.60	30.17	33.37
15	32.17	35.80	32.47	35.03	32.10	35.00	32.23	35.03	31.93	34.57	30.80	33.43
16	32.27	35.77	32.33	35.13	32.33	35.00	32.23	34.83	32.17	33.90	31.57	33.33
17	32.23	35.73	32.30	35.27	32.37	34.87	32.30	34.80	32.43	34.23	32.23	33.53
18	32.17	35.67	32.37	35.10	32.43	34.77	32.33	34.77	32.30	34.17	31.90	33.80
20	32.70	35.90	32.73	35.47	32.70	35.10	32.63	35.07	32.57	34.93	32.23	34.17
21	32.73	36.10	32.93	35.50	32.93	35.43	33.13	35.53	32.93	35.13	32.43	34.63
22	32.70	35.83	32.93	35.20	32.87	35.33	33.17	35.57	32.87	35.10	32.00	34.27
23	32.83	35.90	32.90	35.27	32.90	35.37	33.10	35.63	32.93	35.10	31.97	34.23
24	32.63	35.67	32.87	35.30	33.07	35.33	33.03	35.47	32.83	35.07	31.97	34.27
25	32.53	35.70	32.83	35.07	33.10	35.30	32.90	35.30	32.27	35.00	30.87	33.93
27	32.13	35.47	32.77	35.00	32.97	35.13	32.10	35.13	31.17	34.87	30.40	33.93
28	31.90	35.37	30.93	35.00	31.40	35.00	28.30	34.93	27.93	34.37	27.37	33.40
29	30.57	35.33	28.17	34.87	28.60	34.73	25.90	34.50	25.07	33.87	24.60	32.93
30	31.10	35.07	30.50	34.10	30.67	34.17	30.17	33.97	30.13	33.27	29.90	32.57
31	31.90	35.03	31.89	34.20	31.40	34.13	32.13	33.87	31.93	33.40	31.17	32.47
Monthly average	32.18	35.71	31.99	35.02	32.00	34.95	31.75	34.95	31.54	34.46	30.68	33.58

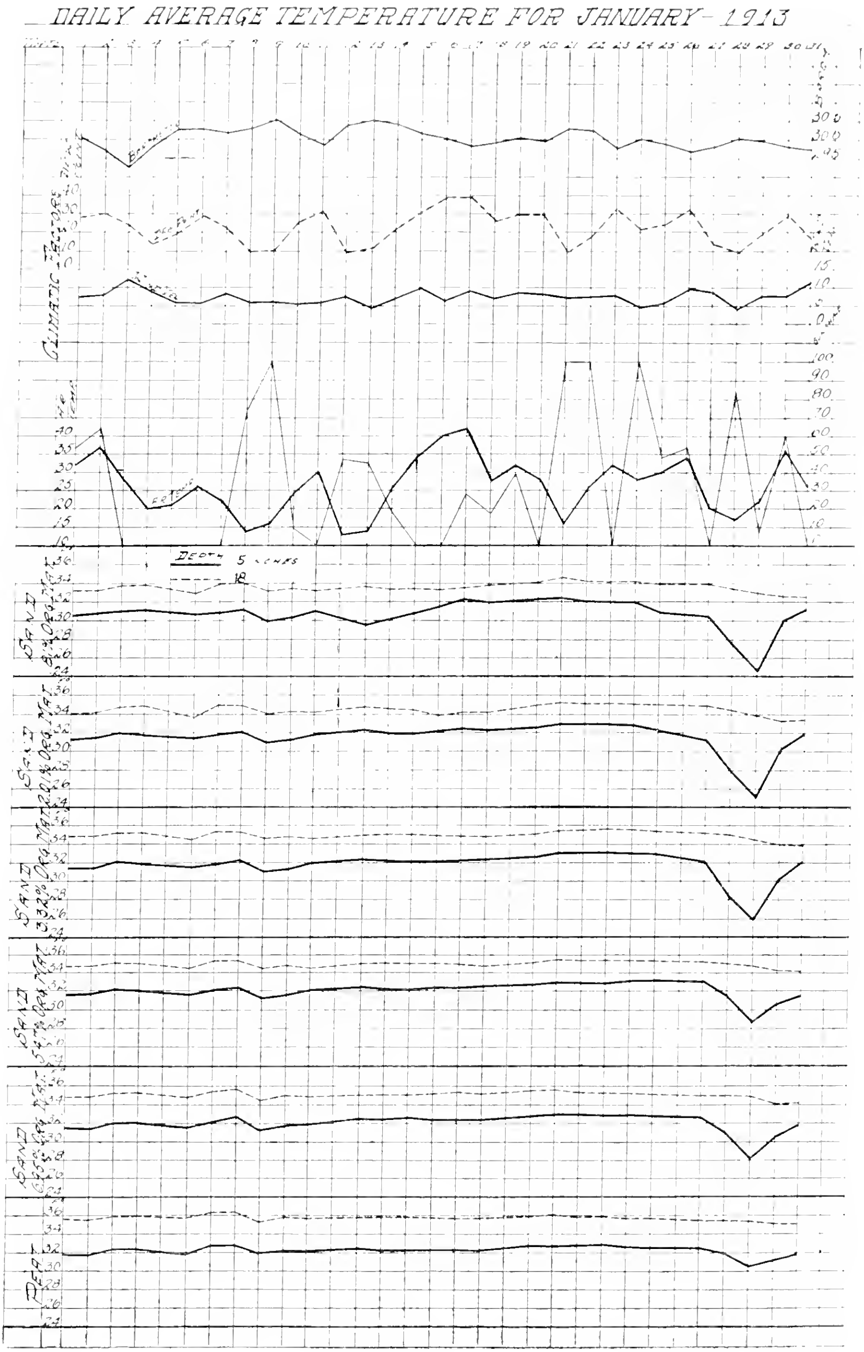
DAILY AVERAGE TEMPERATURE FOR JANUARY—1913
CLIMATIC FACTORS
Barometer
Dew Point
Winds
Air Temp.
Depth 5 inches
12
SAND
PEAT

FIG. 38.

TABLE 57.—EFFECT OF ORGANIC MATTER ON TEMPERATURE OF SOILS. DAILY AVERAGE, FEBRUARY, 1913.

Date.	Peat.		6.95% of Peat.		5.47% of Peat.		3.32% of Peat.		2.01% of Peat.		1.81% of Peat.	
	5″	18″	5″	18″	5″	18″	5	18″	5″	18″	5″	18″
1	28.60	35.10	24.93	34.30	24.73	34.27	23.10	34.10	24.60	33.63	21.53	32.87
3	28.93	34.80	27.70	33.56	28.06	33.23	27.70	33.20	27.33	32.36	26.36	31.30
4	27.56	34.93	25.00	33.63	24.96	33.53	23.93	33.20	23.76	32.30	23.06	30.96
5	23.86	34.53	19.60	33.10	18.86	32.70	17.46	32.33	17.36	30.93	16.73	28.53
6	22.50	34.30	19.20	33.13	18.56	32.23	17.46	31.20	16.80	30.33	16.26	27.70
7	26.33	34.16	24.16	33.76	23.06	31.86	22.20	31.10	22.10	30.96	21.53	29.03
8	27.23	33.73	27.10	32.33	26.70	31.23	25.70	31.20	25.66	31.03	25.10	29.76
10	25.50	33.53	24.56	31.56	24.16	30.70	23.56	31.16	23.36	30.70	22.73	29.10
11	29.20	32.90	28.56	31.23	28.13	31.13	27.23	31.43	27.43	31.13	26.50	30.53
12	23.36	33.33	19.40	31.33	20.06	30.43	18.16	31.06	18.60	30.56	18.43	29.73
13	22.03	33.03	18.76	30.23	19.80	28.80	18.83	29.76	18.43	29.36	17.86	27.36
14	28.56	32.53	24.26	29.16	24.86	28.63	24.96	29.53	24.60	29.30	24.20	28.06
15	29.10	32.17	29.73	30.43	29.43	30.17	29.83	30.70	28.83	30.30	28.37	29.69
17	29.90	32.37	29.60	31.03	29.57	31.17	29.13	31.57	29.13	31.40	28.30	30.67
18	28.50	32.30	27.97	30.70	28.03	30.90	28.73	31.23	28.00	31.03	27.17	29.90
19	31.07	32.33	31.50	31.33	31.97	31.67	31.97	32.13	31.87	32.00	31.00	31.73
20	31.50	32.40	32.07	31.70	32.80	31.97	33.63	32.13	33.03	32.07	31.93	31.80
21	32.13	33.03	32.60	32.47	32.90	32.60	32.73	33.07	32.57	32.77	31.73	32.43
22	31.97	32.73	32.20	32.10	32.47	32.30	32.27	32.80	32.20	32.50	31.53	32.07
24	32.35	32.95	32.35	32.40	32.65	32.65	32.50	32.90	32.25	32.65	31.10	32.25
25	31.89	32.33	31.87	31.90	32.07	32.07	31.90	32.30	31.63	32.20	30.37	31.70
26	31.93	32.80	32.17	32.20	32.27	32.50	32.13	32.67	31.73	32.33	30.97	31.93
27	31.97	32.53	32.10	32.10	32.20	32.27	32.07	32.60	31.90	32.23	31.10	31.87
28	32.00	32.67	32.13	32.17	32.43	32.17	32.20	32.63	31.80	32.37	31.05	31.97
Monthly average	**28.66**	**33.23**	**27.48**	**31.99**	**27.53**	**31.73**	**27.10**	**31.93**	**26.88**	**31.52**	**26.19**	**30.50**

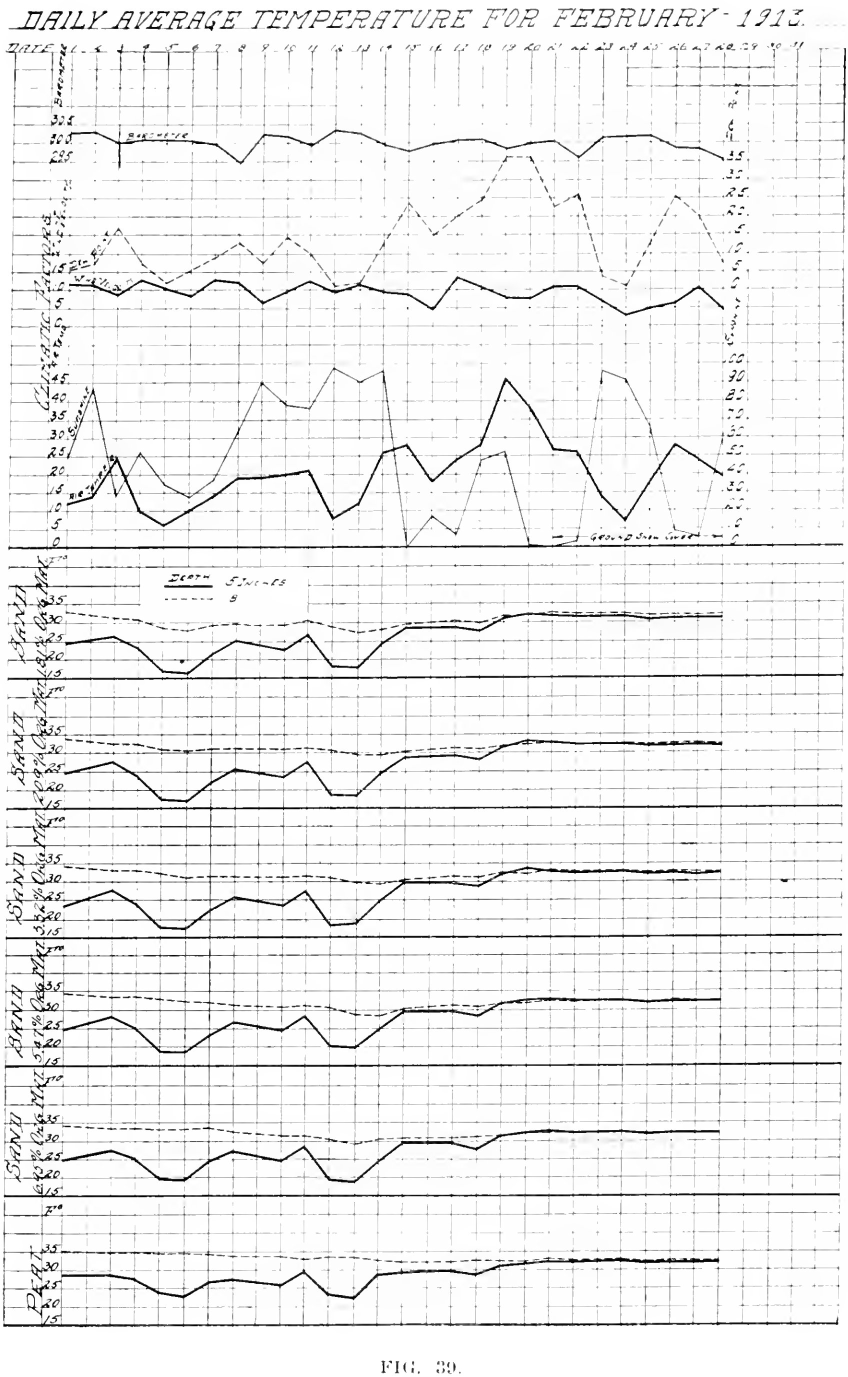
DAILY AVERAGE TEMPERATURE FOR FEBRUARY - 1913.
DATE
BAROMETER
CLIMATIC FACTORS
GROUND SNOW COVER
DEPTH 5 INCHES
8
SAND
PEAT

FIG. 39.

Space does not permit full and detailed discussion of the results of this experiment, hence only the principal points will be emphasized.

All the soils at both depths remained frozen till April 4 on which day the upper 5 inches of the soil with 2.01 and 3.32% organic matter thawed, followed by the soils with 1.81, 5.4 and 6.95% organic matter the next day and by peat 7 days later. The 18 inch depth thawed in the following order: 1.81% organic matter April 10, 2.01% April 10, 3.32% April 11, 5.27% April 12, 6.95% April 15, and peat May 4. Immediately upon thawing the temperature of the soils with the lowest percentage of organic matter rose the highest followed by the other two soils in the order of their increased organic content. On the second day after the first thawing appeared, the temperature of the soil with 1.81% organic matter fell back from that of the soils with 2.01 and 3.32% organic matter but it was still ahead of the temperature of the soils with 5.42 and 6.95% organic matter. The temperature of the two latter soils attained the same magnitude as the temperature of the soils with the three lower percentages of organic matter, about April 15. At about this time the lower depths of the soils with the higher percentages of organic matter thawed, hence the logical inference would seem to be that it was probably these frozen layers below that delayed the rapid rise of the temperature of these soils. The temperature of the soils with the intermediate percentages of organic matter (2.01, 3.32, 5.47%) tended to be higher than that of the soils with 1.81 and 6.95% from the second or third day after thawing to the end of the month of April, and for all the time thereafter. The temperature of the soil with 1.81% organic matter was higher than that of the soil with 6.95% up to the middle of April and from then on it was the latter that was ahead. The temperature of the peat did not attain the same magnitude as that of the other soils until about May 11, or only a few days after the lower depth had thawed.

The temperature of all the soils at both depths continued to increase until July when the maximum was attained and then it began to decrease until freezing time. The highest temperature was attained by all soils at the upper 5 inch depth between the 9th and 11th of July. The soil with 1.81% organic matter reached its average maximum on July 9th with 80.23° F., 2.05% July 9th with 82.26°, 3.32% July 9th with 22.33°; 5.47% July 11th with 81.63°; 6.95% July 11th with 82.23°; and peat July 11th with 78.13°. At the 18 inch depth the highest average temperature was reached by the soil with 1.81% organic matter on July 11th with 71°; 2.01% on July 11th with 71.23°; 3.32% on July 11th with 73.13°; 5.47% July 11th with 73.76°; 6.95% July 12th with 71.1°; and peat on July 12th with 72.72°.

From this period on the temperature of all the soils at both depths decreased somewhat irregularly but gradually until the freezing period and then until the minimum was attained. The first freezing occurred about the first part of December, when the soils with the different amounts of organic matter froze about the same time with small variations. The soils with 1.81, 2.01, and 3.33% organic matter froze at the upper 5 inch depth on December 9th, with 5.17% on December 10th, with 6.95% on December 12th, and peat about December 13th. The 18 inch depth of the different soils froze at the following dates: 1.81% organic

matter Feb. 3rd; 2.01% February 5th; 3.32% February 6th; 5.47% February 7th; 6.95% February 10th; and peat February 15th.

The temperature of the upper 5 inch depth of all the soils fluctuated, after the freezing point was reached, as the average temperature varied, and the amount of fluctuation was greatest when the soils were not covered with snow. The lowest average temperature reached by all the soils at the upper depth, was on Feb. 6th with the following results: 1.81% 16.26° F., 2.01% 16.80°, 3.32% 17.46°, 5.47% 18.56° F., 6.95% 19.20°, peat 22.50°. After this date the temperature tended to fluctuate from the above points to 32° until the thawing period.

From the time of thawing to the end of September the soils with 2.01, 3.32, 5.47 and 6.95% organic matter showed a higher daily and monthly average temperature than the soil with 1.81% and peat. This was true at both depths. The temperature of the first three soils tended to be about the same through all the warmer months with a slight difference in favor of the soil with 3.32% organic matter. The temperature of peat ran considerably lower than that of the soil with 1.81% organic matter up to the end of June. From this time on until the freezing period the temperature of both soils ran about the same with a slight difference in favor of peat.

It will now be worth while to study the moisture content of these soils and compare this with their heat relationships and thereby see to what extent the object of this research has been answered.

The water content of these soils was determined several times during the warmer part of the year, but for the sake of brevity, only three determinations will be given, namely those taken April 3rd, when the soils commenced to thaw, July 27th, in the warmest month of the year, and November 4th, when the rapid cooling commenced. The data are represented herewith:

TABLE 59.—MOISTURE CONTENT OF SOIL WITH DIFFERENT AMOUNTS OF ORGANIC MATTER. FIVE INCH DEPTH.

Date.	1.81%	2.01%	3.32%	5.47%	6.95%	Peat.
April 3	16.96	12.92	21.80	26.90	32.53	256.5
July 27	2.08	3.69	6.78	12.83	17.42	236.4
November 4	2.46	5.85	8.63	14.46	21.8	247.8

It will be seen that the moisture content for all the soils varied considerably at the different times, but it increased very markedly in all of them, with the increase of the organic content. In the determinations of July and November the soil with 6.95% organic matter contained about 9 times as much water as the soil with only 1.81%, while the peat possessed almost 120 times as much as the latter and about 12 times as much as the former.

These facts lead to the important conclusion that color plays an important part in the warming of the soil and contradicts the common belief that its influence or effect is overbalanced or overshadowed by the greater moisture content that the colored soils tend to possess. The results above show conclusively that when the soils are colored,

even in different degrees of shade, so that the reflection is considerably reduced, if not entirely eliminated, their temperature is about the same, irrespective of their moisture content, and that it is higher than that of the uncolored soil whose reflection is very great and whose moisture content is small.

The question might now be asked why peat did not also have a much higher temperature than the uncolored soil. It would have had if it were not for its water holding peculiarities. Peat or muck has not only a very great water holding capacity but also has the ability to retain and absorb water on the surface, which on account of its slow but continuous evaporation, tends to keep the temperature down. This fact is well illustrated in the following experiments. A piece of ground was covered with a thin layer of peat while another piece was covered with a thin layer of white sand. The temperature records taken several times throughout the summer show that both plots at the depth of 7 inches were equally warm, with a slight difference in favor of the plot covered with the white sand. In another experiment, instead of using peat, dark colored sand was employed. The results show that the temperature of the dark covered soil was from 4° to 7° F., higher than that of the white covered soil. In still another experiment, wooden boxes 12 inches square and 2 inches high were filled with white sand, black dyed sand, and peat, in the dry condition, and placed out in the sun and the temperatures were taken many times during the day for several days. The results show that the temperature of the black sand was always about 5° to 6° F., higher than that of the white sand, while the temperature of the peat was lower than that of the black sand and only about 1° or 2° F., higher than that of the white sand. The results under the investigation of the temperature of the different types of soil show also that when the peat was covered with a thin layer of a sandy soil its temperature was little higher during the warmest part of the year than that of the other soils. All these facts go to prove, therefore, that the high heat absorptive power of pure peat, on account of its black color, is considerably reduced by its other properties and consequently its temperature is below that of the other types of soil.

The color of soils differs considerably. It merges into different shades of the same color or into the various colors of the spectrum. The different colors of the spectrum such as blue, green, red, yellow, etc., are found in soils. Some of them occur very rarely. There are various causes of these colors, chief of which are the humus and the iron compounds. All these natural colors, as shown by the present investigation and by the research under absorption, play a very important part in the heat relationship of the soil.

Nothing very definite can be said as to the influence of color on the temperature of soils covered with vegetation. An experiment was commenced to ascertain an answer to this question but it was too late in the season and the results obtained cannot be absolutely relied upon. It would seem, however, that extreme shades of color, such as black and white, would impart to the soils different heat relationships and especially during the early part of plant growth, which is the most important in the life history of plants. Even when the vegetation is well advanced, if the planting has not been too thick so the sun rays

are entirely intercepted, the color will influence the warmth of the soil.

As to the influence of the meteorological elements on the temperature of these soils, the reader can obtain a better idea by referring to the charts for each month. It will suffice to mention again that these elements are too complex in their behavior and consequently the influence of all of them is not very regular.

DAILY AND MONTHLY RANGE OF TEMPERATURE.

In the following tables with their respective charts, is shown the highest and lowest temperature as recorded tri-urnally. What has already been said concerning them under the discussion of the temperature of the different types of soil applies to the present case equally well.

The tables contain the maximum and minimum temperature, while the charts contain the differences or amplitudes of these maxima and minima temperatures. The air temperature is also the range. All the other weather elements are the averages.

TABLE 58. EFFECT OF ORGANIC MATTER ON TEMPERATURE OF SOILS. DAILY MAXIMUM AND MINIMUM, MARCH, 1912.

Date	Maximum, minimum.	Peat.		6.95% Org. Mat.		5.47% Org. Mat.		3.32% Org. Mat.		2.01% Org. Mat.		1.81% Org. Mat.	
		5"	18"	5"	18"	5"	18"	5"	18"	5"	18"	5"	18"
1	Max	32.0	32.2	32.2	32.2	32.4	32.4	32.3	32.5	32.2	32.2	31.9	32.1
	Min	31.9	32.2	32.0	32.1	32.0	32.3	32.0	32.4	32.0	32.2	31.7	32.0
2	Max	31.9	32.4	31.9	32.3	32.0	32.2	32.1	32.7	32.1	32.5	31.6	32.0
	Min	31.5	32.2	31.9	32.0	31.9	32.0	32.0	32.5	32.0	32.3	31.4	31.8
4	Max	31.4	32.3	32.2	32.2	32.3	32.2	32.3	32.4	31.6	32.2	30.3	31.8
	Min	31.0	32.3	32.0	31.9	32.0	32.0	32.0	32.2	30.5	32.2	30.0	31.6
5	Max	30.8	32.0	31.5	32.0	31.2	31.9	31.2	32.0	30.3	32.1	30.0	31.8
	Min	30.0	32.0	31.2	31.9	30.2	31.8	30.9	32.0	29.4	32.1	29.0	31.3
6	Max	30.0	32.1	30.9	31.9	30.0	32.0	30.4	32.2	29.6	32.0	29.3	31.2
	Min	29.1	32.0	30.0	31.5	29.0	31.6	29.4	31.6	28.6	31.5	29.0	30.9
7	Max	29.5	32.1	30.6	32.0	30.0	32.1	30.2	32.2	29.0	31.8	28.9	31.0
	Min	28.8	32.0	29.6	31.8	29.5	32.0	29.5	32.0	28.5	31.3	27.9	30.5
8	Max	29.3	32.3	30.5	32.2	30.2	32.3	30.4	32.3	30.0	32.0	29.0	31.0
	Min	29.3	31.9	30.2	31.0	30.0	31.5	30.0	32.1	29.9	31.3	29.0	30.8
9	Max	29.7	32.0	31.0	32.0	30.5	31.9	30.3	32.1	29.5	32.0	29.4	30.8
	Min	29.6	31.9	30.8	31.9	30.4	31.7	30.2	32.0	29.0	32.0	28.9	30.7
11	Max	30.0	32.3	30.9	32.2	30.5	32.0	30.7	32.3	31.0	32.0	30.0	32.1
	Min	29.9	31.9	30.4	31.9	30.1	31.5	29.9	32.0	29.6	31.0	28.5	30.9
12	Max	30.1	31.9	31.2	31.9	30.3	31.7	30.3	31.9	30.2	31.0	29.2	30.8
	Min	29.9	31.9	30.9	31.7	30.3	31.4	30.1	31.8	29.7	30.8	28.9	30.7
13	Max	30.6	32.0	31.2	31.8	30.8	32.0	30.9	31.4	30.8	31.9	29.9	31.3
	Min	30.0	31.5	30.2	31.4	30.2	31.4	30.4	31.2	30.0	31.5	29.2	30.7
14	Max	30.0	31.7	30.2	31.6	30.2	31.5	30.3	31.7	29.9	31.2	29.0	30.8
	Min	28.5	30.2	29.2	29.9	28.8	30.0	29.1	30.3	29.0	30.0	28.0	29.5
16	Max	30.4	31.3	30.5	32.0	31.0	31.4	31.0	31.7	30.9	31.5	30.5	31.4
	Min	30.0	30.9	30.2	31.1	30.0	31.0	30.0	31.4	30.0	31.2	29.6	30.8
18	Max	30.3	31.4	31.0	31.6	31.2	31.5	31.9	31.9	31.4	31.9	30.7	31.1
	Min	29.2	31.1	30.8	31.3	31.0	31.2	31.0	31.8	31.2	31.8	30.4	31.0
19	Max	31.1	31.5	31.3	31.6	31.4	31.4	31.4	31.9	31.3	31.9	30.9	31.2
	Min	30.5	31.2	31.0	31.3	31.0	31.2	30.9	31.5	31.0	31.7	30.4	31.1
20	Max	27.9	28.4	27.4	28.2	28.1	28.7	28.2	28.8	28.1	28.9	27.8	28.3
	Min	25.0	26.0	25.0	25.0	25.2	26.8	25.5	26.0	25.8	26.9	25.1	25.9
21	Max	29.0	30.5	30.0	30.8	30.4	31.5	31.2	31.4	31.1	31.5	30.3	30.7
	Min	28.0	29.4	29.8	30.1	29.5	30.0	29.8	30.3	29.9	30.1	29.2	30.0
22	Max	30.5	30.5	30.3	30.5	30.6	30.9	30.6	31.4	31.1	31.0	30.4	31.1
	Min	28.9	29.4	29.1	30.0	29.6	29.8	28.0	30.0	29.7	29.4	29.0	30.0
23	Max	29.1	31.4	30.9	30.9	31.2	31.7	31.4	31.7	31.4	32.0	31.0	31.6
	Min	28.0	30.5	30.4	30.4	31.0	31.1	31.0	31.5	31.3	31.6	30.5	31.2
25	Max	30.8	31.4	31.0	31.8	31.7	31.9	32.0	31.7	31.5	31.7	31.0	31.4
	Min	29.8	30.5	30.5	30.4	31.0	31.3	31.5	31.2	30.6	31.1	30.8	31.1
26	Max	31.0	31.5	31.3	31.6	31.9	31.7	31.5	32.1	32.1	31.7	31.1	31.2
	Min	30.9	31.1	30.8	31.1	31.7	31.4	31.0	31.9	31.8	31.2	30.8	30.9
27	Max	31.2	31.8	31.7	31.8	32.1	32.1	31.8	32.2	31.9	32.1	31.2	31.9
	Min	30.3	31.6	31.5	31.7	31.8	32.0	31.6	31.7	31.7	31.7	31.0	31.4
28	Max	31.2	31.5	31.9	31.7	32.0	31.9	32.0	32.4	31.6	32.1	31.1	31.8
	Min	30.6	31.3	31.3	31.2	31.8	31.7	30.6	31.9	31.3	31.7	31.0	31.4
29	Max	31.9	32.2	31.8	31.9	31.9	31.8	31.5	32.1	32.1	32.0	31.5	31.7
	Min	31.3	32.0	31.4	31.5	31.8	31.3	31.0	32.0	31.7	31.3	30.7	31.0
30	Max	31.8	32.1	31.0	32.0	31.3	31.7	31.5	32.1	31.7	31.6	31.9	31.4
	Min	31.3	31.8	29.8	30.7	29.2	31.1	29.7	31.7	31.4	31.2	30.9	31.2
Monthly range		0.72	0.48	0.57	0.64	0.66	0.52	0.79	0.44	0.67	0.56	0.68	0.52

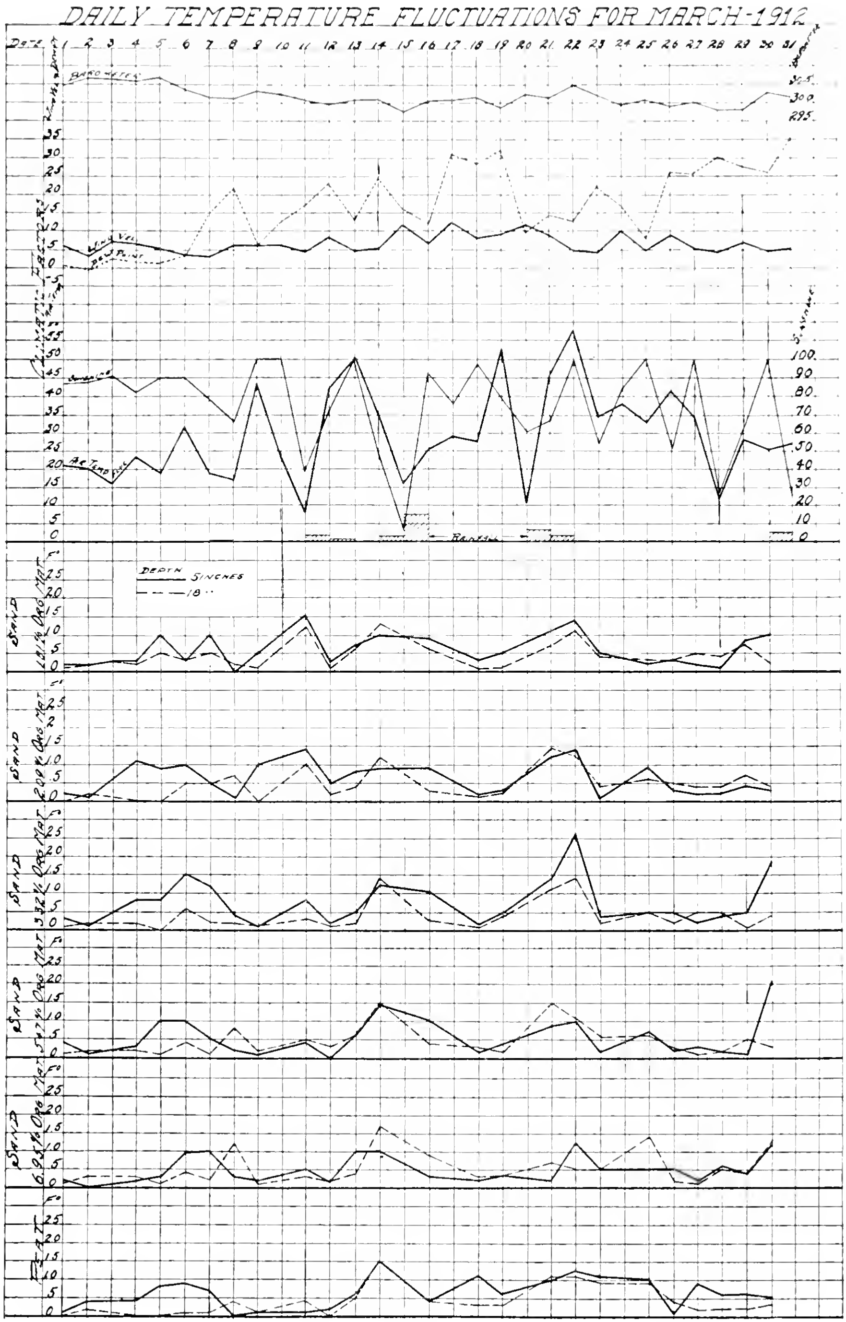
DAILY TEMPERATURE FLUCTUATIONS FOR MARCH-1912
BAROMETER
WIND VEL.
DEW POINT
SUNSHINE
AIR TEMP.
RAINFALL
DEPTH 5 INCHES
18 ..
SAND 1.31% ORG. MAT.
SAND 2.00% ORG. MAT.
SAND 3.32% ORG. MAT.
SAND 5.47% ORG. MAT.
SAND 6.95% ORG. MAT.
PEAT

FIG. 40.

TABLE 59.—EFFECT OF ORGANIC MATTER ON THE TEMPERATURE OF SOILS. DAILY MAXIMUM AND MINIMUM, APRIL, 1912.

Date	Maximum, minimum.	Peat.		6.95% Org. Mat.		5.47% Org. Mat.		3.32% Org. Mat.		2.01% Org. Mat.		1.81% Org. Mat.	
		5"	18	5"	18"	5"	18"	5"	18"	5"	18"	5"	18"
1	Max	32.0	32.0	32.3	32.1	32.4	32.2	32.1	32.2	32.4	32.4	32.0	32.0
	Min	31.7	31.4	32.0	31.7	31.9	31.9	31.9	31.8	32.0	32.1	31.2	31.3
2	Max	31.9	32.0	31.6	31.3	31.8	31.5	31.9	31.7	31.9	31.9	31.3	31.4
	Min	31.4	31.4	31.5	31.0	31.3	31.5	31.2	31.5	30.4	31.0	30.3	30.5
3	Max	31.5	31.8	31.5	31.5	31.7	31.6	31.5	31.6	32.0	31.6	31.1	31.3
	Min	30.8	31.4	31.1	31.0	31.2	31.3	31.3	31.2	30.5	31.0	30.0	30.3
4	Max	31.4	31.6	31.8	31.8	31.7	31.7	35.0	31.8	36.7	31.9	31.9	30.7
	Min	31.0	31.0	30.0	30.0	31.3	30.0	31.9	30.6	31.1	30.9	29.1	30.0
5	Max	31.5	31.9	35.9	31.9	40.4	31.9	44.0	32.1	45.0	31.7	40.0	31.2
	Min	31.4	31.7	31.9	31.6	32.9	31.7	34.5	31.9	35.0	31.6	32.4	31.1
6	Max	31.5	31.9	41.9	31.5	46.2	31.9	49.9	32.0	49.7	31.9	46.5	31.3
	Min	31.0	31.5	34.6	31.3	36.1	31.5	38.0	31.7	38.0	31.5	36.5	31.2
7	Max	31.5	31.8	34.5	31.5	36.0	31.9	35.7	31.9	35.8	31.7	35.0	31.1
	Min	31.3	31.4	33.3	31.3	34.5	31.3	34.1	31.5	34.6	31.5	33.5	31.0
8	Max	31.5	31.8	39.9	31.7	41.9	31.7	43.9	32.1	43.9	31.8	41.2	31.2
	Min	31.4	31.4	31.6	31.3	32.0	31.4	31.4	31.5	31.6	31.6	30.9	31.1
9	Max	31.4	31.8	45.0	31.7	47.6	31.6	50.1	32.0	49.1	31.8	47.9	32.5
	Min	31.1	31.7	34.4	31.6	35.1	31.6	35.0	31.9	35.8	31.7	34.0	31.2
10	Max	31.7	31.6	46.6	31.6	49.7	31.7	51.6	31.6	50.5	33.2	47.0	35.0
	Min	31.0	31.5	33.0	31.5	33.9	31.3	33.2	31.2	33.2	31.9	32.3	32.1
11	Max	34.5	31.6	49.1	31.6	53.4	31.6	55.9	36.8	54.5	36.4	52.0	38.0
	Min	31.7	31.5	35.5	31.5	36.9	31.5	37.4	33.5	37.2	33.4	36.0	34.9
12	Max	36.0	31.6	46.9	31.6	49.1	35.0	51.0	38.9	50.3	39.0	48.0	39.0
	Min	32.8	31.6	39.7	31.6	42.8	31.7	42.5	37.9	42.5	37.5	41.5	37.9
13	Max	36.4	31.5	45.0	31.5	49.1	39.0	50.6	40.0	49.4	39.4	47.7	39.5
	Min	33.1	31.4	38.9	31.3	41.2	37.6	41.8	39.0	41.8	38.9	40.1	38.6
15	Max	42.0	31.5	55.6	41.5	55.0	43.8	56.0	44.5	55.9	44.5	54.5	44.3
	Min	36.0	31.5	41.1	40.1	44.8	42.0	41.0	38.4	41.0	38.8	39.9	38.0
16	Max	41.5	32.1	50.9	43.2	51.5	44.5	52.5	44.3	50.9	44.0	48.5	43.3
	Min	36.0	31.7	45.1	42.0	45.4	42.5	45.0	42.5	44.8	42.0	43.3	41.8
17	Max	37.9	31.7	45.0	43.5	46.8	43.9	48.8	43.8	47.2	43.4	44.3	42.0
	Min	34.0	31.4	42.9	42.0	41.5	42.5	40.0	43.0	40.0	42.1	39.0	41.5
18	Max	36.8	31.9	41.3	42.2	41.6	42.3	41.0	41.5	41.0	40.5	39.2	39.5
	Min	34.1	31.8	39.5	41.5	39.5	40.9	39.0	41.2	38.5	40.0	37.5	39.5
19	Max	39.9	31.8	47.4	40.5	48.5	40.5	49.0	41.5	48.0	41.0	45.0	40.1
	Min	32.2	31.7	36.0	40.0	35.2	40.0	34.5	39.6	33.9	38.0	32.9	37.0
20	Max	41.0	32.4	48.5	42.0	49.0	42.5	55.4	49.9	50.0	40.7	51.8	40.0
	Min	35.0	31.2	35.6	38.0	39.0	38.9	37.8	39.0	37.5	37.0	36.0	37.2
22	Max	42.0	31.9	48.8	44.5	49.0	45.0	48.7	45.4	48.5	45.2	47.2	44.9
	Min	40.3	31.9	46.2	44.3	45.5	41.9	44.0	44.9	43.9	41.9	42.3	44.8
23	Max	39.8	32.0	50.9	43.8	51.0	43.5	52.2	43.9	51.8	42.8	49.4	42.8
	Min	34.3	31.8	38.9	42.4	37.5	42.3	35.8	42.3	35.8	41.5	34.4	40.0
24	Max	45.0	31.9	56.5	43.9	57.0	44.3	58.1	45.2	57.0	45.1	53.8	45.2
	Min	38.5	31.7	45.3	43.7	45.3	43.8	45.1	43.6	44.8	43.9	44.0	43.4
25	Max	42.9	31.8	55.3	45.0	56.1	45.1	58.9	45.2	57.8	45.4	55.0	45.0
	Min	37.0	31.2	41.9	44.1	41.2	44.2	40.0	44.1	39.5	43.5	38.0	42.3
26	Max	47.1	31.9	57.5	45.5	58.6	46.9	61.5	47.3	61.1	47.9	59.1	47.9
	Min	41.2	31.8	49.0	45.5	49.0	45.9	48.9	46.2	48.8	46.1	47.9	45.4
27	Max	42.0	31.8	57.5	47.5	58.2	47.7	58.0	48.3	57.4	49.0	54.0	48.1
	Min	40.0	31.8	47.2	47.0	48.0	47.3	46.3	47.3	46.6	47.1	45.0	46.4
29	Max	37.8	32.0	45.0	44.9	45.1	44.9	45.5	44.5	45.2	44.0	44.0	42.9
	Min	37.2	31.9	42.6	44.4	42.5	44.1	41.8	44.0	41.8	43.6	40.0	42.4
30	Max	39.5	31.8	58.0	43.7	59.0	43.9	60.9	44.8	60.0	45.0	56.1	44.5
	Min	35.9	31.6	48.8	42.9	37.2	42.8	36.8	42.4	36.9	42.0	36.0	41.0
Monthly range		2.57	0.28	7.03	0.69	8.29	0.93	10.33	1.55	8.85	1.39	5.23	1.60

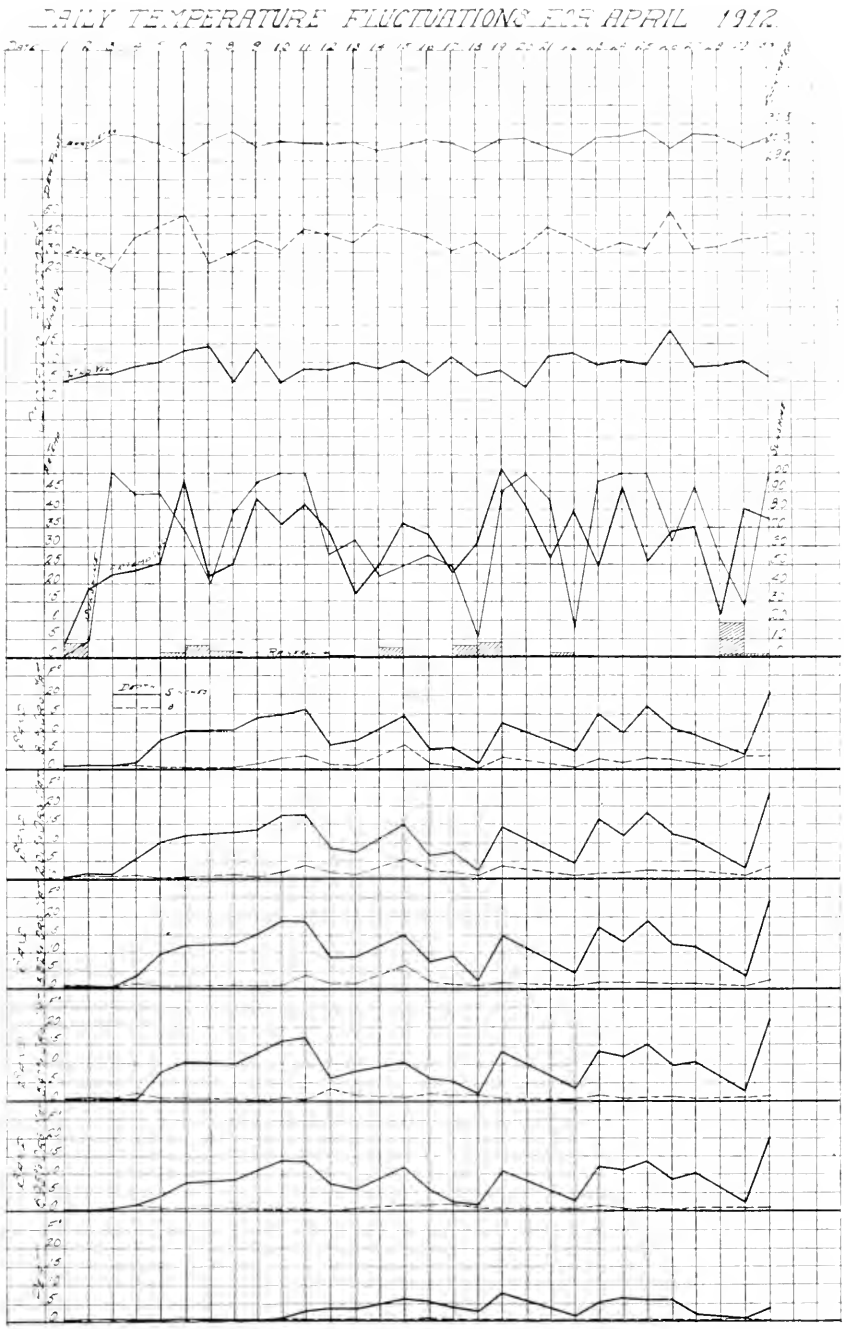

FIG. 41.

TABLE 60. — EFFECT OF ORGANIC MATTER ON TEMPERATURE OF SOILS. DAILY MAXIMUM AND MINIMUM, MAY, 1912.

Date	Maximum, minimum.	Peat. 5″	Peat. 18″	6.95% Org. Mat. 5″	6.95% Org. Mat. 18″	5.47% Org. Mat. 5″	5.47% Org. Mat. 18″	3.32% Org. Mat 5″	3.32% Org. Mat 18″	2.01% Org Mat. 5″	2.01% Org Mat. 18″	1.81% Org. Mat. 5″	1.81% Org. Mat. 18″
1	Max	40.0	32.0	49.8	45.7	50.3	45.9	51.0	46.0	50.6	45.7	48.9	45.0
	Min	39.1	31.6	44.4	45.0	44.1	45.0	43.5	44.9	43.4	45.0	41.9	44.0
2	Max	43.5	32.1	60.6	46.0	61.4	46.5	62.9	46.3	62.0	47.8	59.0	47.5
	Min	39.9	31.9	44.3	45.0	44.2	44.9	44.2	45.1	43.1	45.0	42.9	44.5
3	Max	47.0	32.1	65.2	48.1	65.3	49.3	66.8	50.0	65.7	50.5	62.5	50.3
	Min	43.8	31.9	49.4	47.4	49.3	47.4	49.0	47.7	49.5	47.8	46.9	47.3
4	Max	49.0	32.4	67.0	50.0	67.0	50.8	68.0	51.5	67.1	52.0	63.3	52.0
	Min	46.0	32.1	51.7	49.5	51.4	49.4	50.0	49.8	50.0	49.8	48.6	49.4
6	Max	54.0	35.9	70.5	52.8	70.2	53.2	71.3	53.9	70.9	54.6	66.5	54.6
	Min	50.2	35.8	53.9	51.5	53.1	51.8	53.0	52.0	52.8	52.0	51.3	51.2
7	Max	56.9	39.8	69.0	54.8	69.2	55.3	72.8	55.9	70.8	56.4	65.8	56.0
	Min	54.0	38.1	57.8	54.1	57.7	54.1	57.0	54.8	56.8	54.7	54.9	54.0
8	Max	56.9	44.9	65.1	55.0	64.8	54.9	65.5	55.5	64.0	55.6	61.1	55.1
	Min	54.0	41.0	53.8	54.2	53.1	54.0	62.3	53.9	51.8	53.8	50.5	52.5
9	Max	55.4	49.9	66.7	54.8	67.0	54.2	66.8	54.4	65.8	54.0	61.2	53.7
	Min	54.0	49.0	51.4	53.4	50.3	53.3	49.2	52.9	49.0	52.7	47.5	51.4
10	Max	58.1	51.4	71.0	54.0	71.7	54.5	71.8	55.0	71.2	55.4	66.3	55.0
	Min	54.0	50.6	51.4	53.4	51.0	53.0	49.5	53.0	49.1	52.5	47.0	51.5
11	Max	57.5	52.0	59.7	55.8	60.0	56.0	60.5	56.0	59.8	56.0	58.0	54.8
	Min	56.6	51.5	58.3	54.2	58.5	54.0	57.5	54.7	57.0	54.4	55.4	54.0
13	Max	51.6	53.0	51.4	50.0	56.8	49.3	57.9	49.2	58.0	49.0	54.0	48.7
	Min	48.5	52.5	42.5	49.4	42.0	48.8	40.4	48.7	40.5	47.9	39.6	46.5
14	Max	53.1	52.3	60.8	51.0	61.2	51.2	61.3	51.9	60.1	51.8	56.6	51.0
	Min	50.2	51.3	46.5	49.8	46.7	49.3	46.4	49.4	46.3	49.2	44.3	47.0
15	Max	50.4	52.0	50.3	51.5	50.4	51.0	51.0	51.9	50.3	50.2	48.5	48.8
	Min	49.7	51.7	46.3	50.0	45.8	50.0	44.4	50.0	44.4	49.3	42.8	48.0
16	Max	49.8	51.3	51.4	50.0	51.3	49.5	50.8	49.2	50.3	49.0	49.0	48.4
	Min	49.5	51.0	47.7	49.0	47.4	49.0	47.0	49.0	47.0	48.7	45.7	47.8
17	Max	51.8	51.4	59.6	49.2	60.6	49.1	62.0	50.0	62.0	50.1	58.2	49.9
	Min	48.8	50.0	47.5	48.5	46.5	48.1	46.0	48.0	45.6	47.8	45.0	47.0
18	Max	51.1	50.7	55.6	50.1	57.8	49.4	60.1	49.5	58.8	50.4	56.6	48.5
	Min	50.1	49.3	46.9	50.1	46.4	49.0	46.1	49.5	47.0	49.6	44.9	47.3
20	Max	54.4	51.0	58.2	51.8	58.7	51.8	58.9	52.0	58.8	52.0	57.4	51.8
	Min	51.8	50.2	51.4	51.5	51.0	51.3	50.2	51.3	49.9	50.6	48.5	49.7
21	Max	58.0	51.8	63.0	53.0	63.1	53.2	61.8	54.0	62.8	54.8	60.8	54.3
	Min	53.4	49.9	53.3	51.3	53.7	51.2	53.6	51.3	53.5	51.3	53.4	50.9
22	Max	61.8	52.8	72.2	55.0	74.3	55.7	77.0	56.9	76.9	57.7	73.2	58.1
	Min	58.0	52.3	57.2	54.1	57.2	54.1	57.7	54.8	57.6	54.8	56.4	54.4
23	Max	65.1	54.0	78.9	57.9	80.1	58.8	80.9	60.0	79.9	60.8	75.8	60.9
	Min	61.8	51.6	62.8	56.5	63.0	57.2	63.8	58.0	63.7	58.4	62.1	58.5
24	Max	66.7	56.0	73.8	60.5	73.2	60.6	73.3	61.4	74.6	61.2	71.9	62.1
	Min	63.5	53.3	65.7	59.5	65.1	60.1	62.1	60.2	64.0	60.4	62.6	60.1
25	Max	66.1	57.2	79.4	60.0	80.0	59.8	80.2	61.1	78.8	61.7	73.6	60.9
	Min	62.1	56.6	58.5	59.1	58.0	59.6	56.7	58.9	57.1	59.2	55.3	58.2
27	Max	68.0	60.4	72.9	62.7	73.8	62.6	74.8	63.0	75.2	63.2	72.5	62.1
	Min	65.6	58.9	66.9	62.0	66.0	61.9	63.0	61.9	64.6	61.7	62.9	60.9
28	Max	66.6	60.1	66.5	62.0	67.9	62.0	68.5	62.2	68.5	62.4	67.0	62.2
	Min	65.9	59.9	65.0	61.8	65.0	61.5	64.9	61.5	64.7	61.8	63.9	61.5
29	Max	64.0	62.0	59.9	61.2	59.3	60.6	59.1	60.9	59.1	60.5	57.4	60.2
	Min	62.0	60.7	59.1	59.6	58.5	59.0	57.2	59.1	57.1	58.9	56.3	58.3
30	Max	63.8	60.4	75.4	58.1	76.5	58.1	78.0	59.4	75.8	59.8	71.3	59.3
	Min	59.3	59.9	54.0	57.2	53.8	56.8	53.8	56.9	53.8	56.9	52.2	54.9
31	Max	66.3	59.5	79.8	60.1	80.7	60.5	81.5	61.2	80.0	61.5	74.7	61.1
	Min	61.9	59.1	58.8	59.2	58.2	58.9	57.9	59.2	57.3	58.8	55.1	57.8
Monthly range		3.07	0.96	11.36	0.92	12.40	1.15	13.67	1.56	13.40	1.89	11.59	2.38

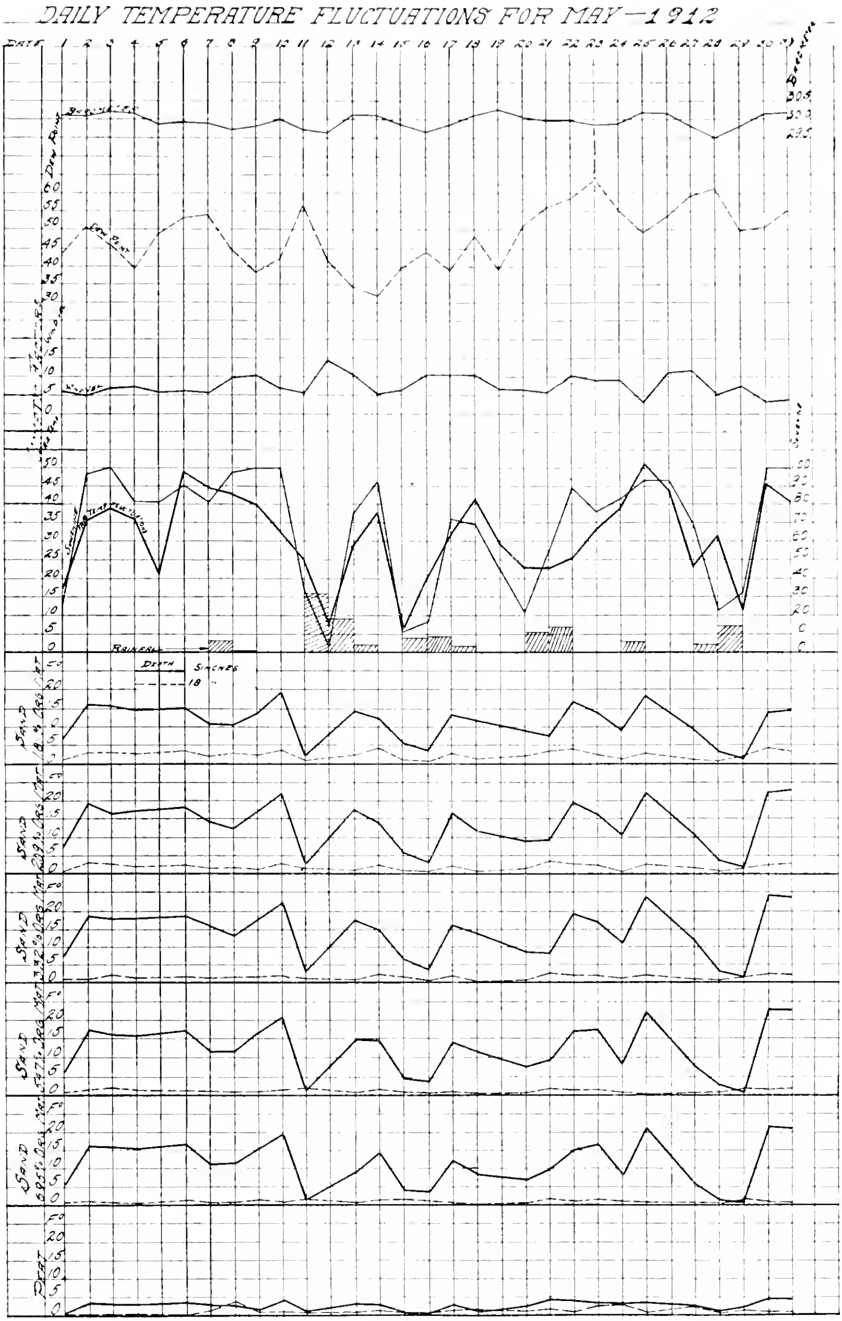
DAILY TEMPERATURE FLUCTUATIONS FOR MAY—1912
DATE
Barometer
Dew Point
Rainfall
Depth
5 inches
18 "
SAND
PEAT

FIG. 42.

TABLE 61.—EFFECT OF ORGANIC MATTER ON TEMPERATURES OF SOILS. DAILY MAXIMUM AND MINIMUM, JUNE, 1912.

Date.—Maximum, minimum.		Peat.		6.95% Org. Mat.		5.47% Org. Mat.		3.32% Org. Mat.		2.01% Org. Mat.		1.81% Org. Mat.	
		5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″
1	Max	69.7	61.0	81.3	62.9	81.9	63.3	82.2	64.0	81.1	64.3	77.0	63.8
	Min	64.6	59.7	61.8	61.7	63.2	61.2	62.4	61.5	62.0	61.0	59.8	60.1
3	Max	67.1	61.0	77.7	61.9	78.3	61.8	79.0	62.6	78.1	63.0	75.6	62.9
	Min	63.8	61.0	60.2	61.0	59.5	60.3	59.2	60.3	58.9	60.0	57.7	59.3
4	Max	66.4	61.5	72.0	62.9	70.9	62.5	71.9	62.6	72.0	62.7	69.3	62.3
	Min	64.6	61.3	61.8	62.1	60.9	61.6	59.8	61.5	59.7	61.2	58.2	60.5
5	Max	64.3	61.8	72.0	61.9	72.0	61.0	73.5	61.1	72.6	61.5	69.1	60.8
	Min	61.9	61.3	56.4	60.5	54.9	59.8	54.4	59.8	54.8	59.3	53.3	58.1
6	Max	66.6	61.3	75.2	62.0	75.1	61.9	75.5	63.0	73.9	63.0	70.3	62.3
	Min	64.0	61.2	63.2	61.4	62.2	60.8	62.0	61.3	62.0	61.0	60.6	60.4
7	Max	65.0	61.4	74.3	62.5	74.4	62.0	74.9	61.9	72.6	61.5	68.1	60.3
	Min	62.3	61.2	58.8	61.3	58.0	60.8	56.2	60.5	55.8	60.0	54.0	58.4
8	Max	64.4	61.3	72.0	62.0	71.9	61.8	72.0	61.8	71.0	61.7	66.6	60.5
	Min	61.6	61.2	58.0	61.0	57.1	60.5	55.8	60.0	54.9	59.1	52.5	57.9
10	Max	66.7	62.3	77.9	64.0	78.0	63.6	77.9	63.6	76.4	63.0	72.5	62.2
	Min	64.2	61.0	61.4	62.0	60.5	61.7	59.0	61.2	58.2	60.5	56.3	59.1
11	Max	66.6	61.3	77.1	63.8	77.7	63.5	78.0	63.3	77.0	63.4	73.7	62.8
	Min	64.0	61.3	62.1	62.8	61.8	62.1	60.3	62.0	59.8	61.4	58.9	60.0
12	Max	68.7	62.0	77.5	64.2	77.5	64.2	77.1	64.5	76.0	64.5	73.5	64.5
	Min	66.4	61.8	67.5	64.0	66.9	63.9	66.0	63.9	65.8	63.4	61.1	62.9
13	Max	68.3	62.5	78.0	64.9	78.0	64.3	78.1	64.2	77.0	64.4	74.0	64.1
	Min	65.3	62.3	62.4	63.9	61.7	63.4	60.2	63.1	59.8	62.5	58.0	61.7
14	Max	66.8	63.0	66.7	65.1	66.5	65.0	66.0	64.9	65.3	64.3	63.5	63.5
	Min	65.4	63.0	64.3	63.7	64.0	63.0	62.8	63.0	62.3	62.4	60.9	62.0
15	Max	68.2	62.8	75.8	63.0	75.2	63.3	74.8	64.0	74.0	64.4	72.0	64.5
	Min	64.8	62.7	64.0	62.4	64.2	62.2	64.7	62.2	64.2	61.9	63.4	61.2
17	Max	69.1	63.7	78.7	65.0	78.4	64.9	79.0	65.1	78.0	65.6	74.7	65.2
	Min	66.1	63.2	62.5	63.9	62.0	63.7	60.9	63.8	60.8	63.3	59.8	62.5
18	Max	66.5	63.3	74.5	64.6	75.6	64.5	76.1	64.3	74.8	63.8	71.1	63.1
	Min	64.9	63.2	61.9	63.7	61.1	63.4	59.4	63.2	58.9	62.7	57.0	61.5
19	Max	68.0	63.5	75.3	64.5	75.3	64.5	75.8	65.0	74.8	65.1	71.4	64.6
	Min	65.2	62.8	63.4	63.7	62.8	63.3	61.7	63.4	61.2	63.0	59.8	62.0
20	Max	67.5	63.1	76.2	64.2	76.3	64.0	77.0	64.4	76.2	64.6	73.1	64.2
	Min	65.0	63.0	62.9	63.7	62.0	63.4	60.7	63.4	60.2	62.9	58.6	61.9
21	Max	68.4	63.5	78.0	64.6	78.0	64.5	77.9	64.9	76.8	65.0	73.2	64.4
	Min	65.5	63.0	63.2	64.3	62.1	63.9	60.9	63.9	60.1	63.5	58.5	62.5
22	Max	69.5	63.6	81.0	65.0	81.1	65.0	81.7	65.5	80.2	65.8	77.0	65.1
	Min	65.4	63.2	62.5	64.3	61.7	61.0	60.4	63.9	59.5	63.2	57.9	62.2
24	Max	70.5	64.3	78.8	67.0	78.7	67.1	78.9	67.1	78.0	67.0	75.7	66.6
	Min	68.4	64.0	67.1	66.4	66.3	66.3	65.2	66.2	61.6	65.9	63.0	65.0
25	Max	71.7	65.0	83.0	67.4	83.0	67.1	83.5	67.5	83.1	68.0	80.4	68.0
	Min	68.3	64.9	66.8	66.1	66.2	66.0	65.2	66.0	64.8	65.7	63.3	65.0
26	Max	72.9	65.4	80.8	68.0	80.2	68.1	80.3	68.9	79.9	69.0	78.0	69.1
	Min	69.7	65.0	68.9	67.4	68.2	67.2	67.5	67.4	67.0	67.0	65.4	66.5
27	Max	71.9	66.0	79.8	68.2	79.7	68.1	79.9	68.4	79.3	68.0	77.5	68.1
	Min	70.0	65.5	68.6	67.1	68.0	67.4	67.1	67.8	66.6	67.3	65.4	66.7
28	Max	73.3	66.0	82.2	68.0	81.5	67.9	81.5	68.4	81.0	68.8	79.2	69.0
	Min	69.5	65.8	67.9	67.0	67.2	66.8	66.2	67.0	66.0	66.6	64.7	66.2
29	Max	72.0	68.5	79.8	69.0	79.7	68.9	80.7	69.0	80.2	68.9	78.3	68.2
	Min	71.5	63.8	70.0	65.8	69.7	66.0	68.9	66.6	68.3	63.9	66.8	64.0
Monthly range		2.71	0.33	13.51	0.97	14.20	1.20	15.44	1.47	14.92	2.08	13.48	2.52

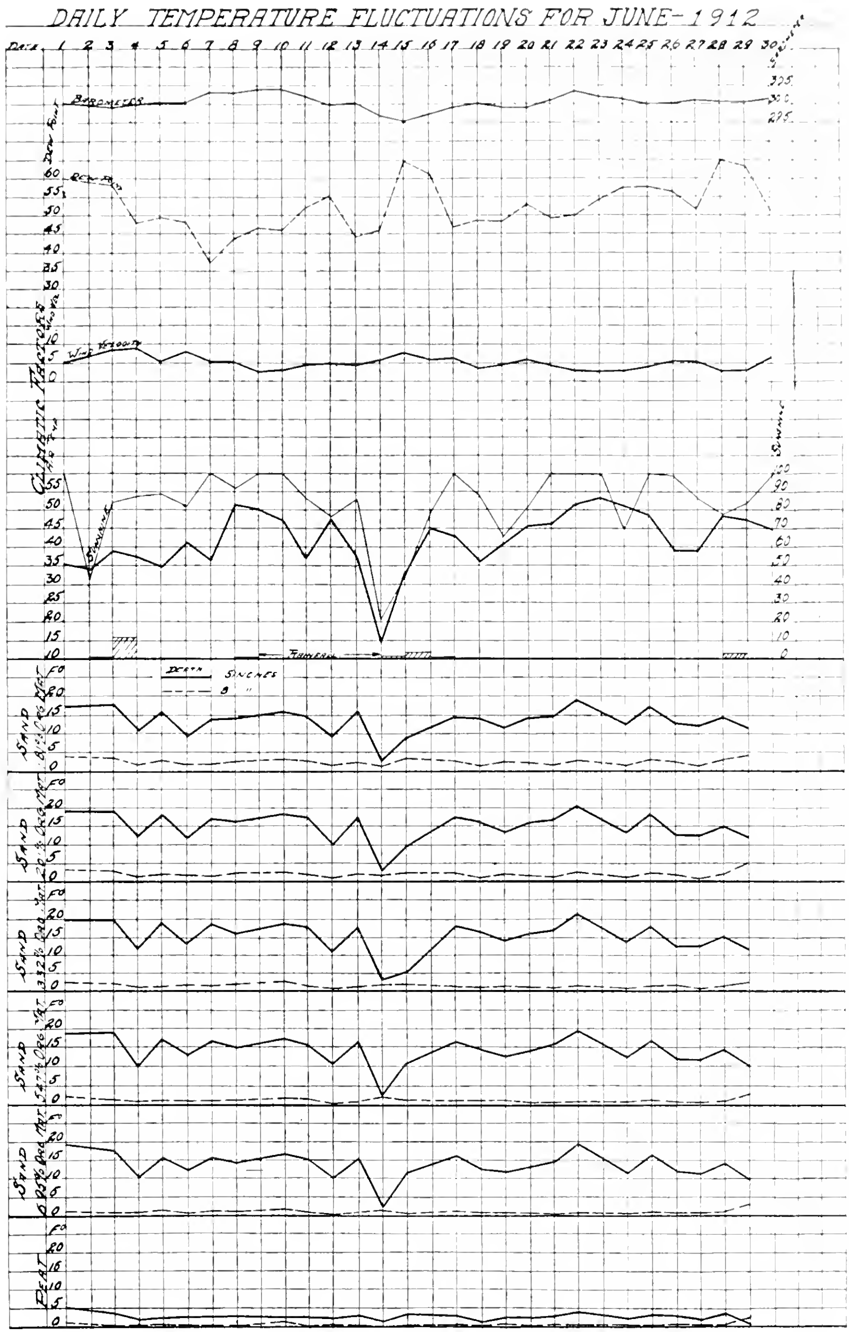
DAILY TEMPERATURE FLUCTUATIONS FOR JUNE-1912
DATE
BAROMETER
DEW POINT
WIND VELOCITY
CLIMATIC FACTORS
SUNSHINE
RAINFALL
DEPTH 3 INCHES
8 "
SAND
PEAT

FIG. 43.

TABLE 62.—EFFECT OF ORGANIC MATTER ON TEMPERATURE OF SOILS. DAILY MAXIMUM AND MINIMUM, JULY, 1912.

Date—Maximum, minimum.		Peat.		6.95% Org. Mat.		5.47% Org. Mat.		3.32% Org. Mat.		2.01% Org. Mat.		1.81% Org. Mat.	
		5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″
1	Max	72.0	67.8	81.2	69.7	80.8	69.3	81.1	69.4	80.8	69.0	78.8	68.0
	Min	69.2	66.5	66.2	67.4	65.9	67.4	64.6	67.4	64.1	67.0	62.4	66.0
2	Max	73.1	67.5	81.4	69.3	80.9	69.2	81.1	69.3	81.0	69.1	79.4	69.0
	Min	69.7	66.2	69.5	67.4	69.0	67.2	68.0	67.2	67.7	67.0	66.3	66.4
3	Max	74.7	68.0	83.0	70.0	82.2	69.9	82.0	70.1	81.9	70.0	80.2	70.2
	Min	72.9	66.1	72.2	68.8	71.7	68.9	71.1	69.3	70.7	69.6	69.6	69.4
4	Max	76.0	67.4	85.0	70.0	84.1	70.0	84.3	70.2	84.2	70.7	82.5	71.0
	Min	72.1	67.0	71.6	69.0	71.2	68.6	70.2	68.7	69.9	68.6	68.6	68.2
5	Max	77.2	68.8	83.6	71.5	83.1	71.7	83.1	72.0	83.1	72.2	81.8	72.4
	Min	74.4	68.0	75.3	70.3	75.0	70.3	74.1	70.4	74.1	70.5	73.0	70.5
6	Max	78.1	70.0	83.9	72.0	81.9	72.1	81.9	72.9	81.6	73.2	79.8	73.7
	Min	75.3	69.4	74.9	71.8	74.5	71.5	73.7	71.8	73.6	71.7	72.6	71.6
8	Max	78.2	70.9	86.0	71.6	85.2	71.4	85.2	72.3	85.0	73.0	82.9	73.4
	Min	74.7	70.6	72.7	71.0	72.2	70.7	71.3	70.9	71.1	70.7	70.0	70.3
9	Max	79.5	71.0	88.5	72.2	88.4	72.2	89.4	73.2	89.6	74.0	87.1	74.5
	Min	75.4	70.1	74.3	71.2	74.0	71.1	73.0	71.2	72.6	71.3	71.3	71.2
10	Max	79.6	71.9	84.9	73.9	83.8	73.8	83.5	74.9	83.6	75.0	82.2	75.7
	Min	77.1	71.0	76.4	73.2	75.9	73.1	75.0	73.3	74.8	71.1	73.4	71.0
11	Max	80.2	72.5	88.6	74.3	87.1	74.1	87.0	74.5	86.7	74.9	84.5	75.0
	Min	77.0	72.3	75.7	73.6	75.0	73.3	74.1	73.6	73.8	73.4	72.5	73.1
12	Max	78.7	72.8	85.0	74.7	84.2	74.3	84.0	74.4	84.0	74.2	82.2	74.0
	Min	76.0	72.7	71.2	73.8	73.5	73.3	72.2	73.3	71.9	73.0	70.2	72.3
13	Max	77.0	73.2	77.0	74.2	77.2	74.0	77.3	74.1	77.4	74.1	76.2	73.6
	Min	74.5	72.9	72.7	72.9	72.0	72.5	71.2	72.5	71.0	72.4	70.0	72.2
15	Max	79.7	72.4	83.5	73.2	83.1	73.2	85.3	74.9	84.6	75.1	82.1	75.1
	Min	77.2	72.3	75.0	72.7	74.6	72.7	75.0	73.2	75.0	73.6	74.0	73.4
16	Max	76.3	72.9	83.7	72.9	84.3	72.3	85.2	72.4	84.8	72.0	81.0	71.2
	Min	72.4	72.0	65.9	71.0	61.3	70.7	63.0	70.9	63.0	70.3	61.6	69.1
17	Max	78.2	72.0	87.1	72.3	87.9	72.3	88.5	73.2	87.9	73.5	84.3	73.2
	Min	74.3	71.7	71.9	71.3	71.2	71.2	70.7	71.7	70.3	71.3	67.7	70.0
18	Max	75.0	72.0	72.2	73.2	71.8	73.2	71.0	73.4	70.2	73.2	68.9	72.0
	Min	72.9	71.8	71.3	71.8	70.8	71.4	69.3	71.4	69.0	71.0	67.7	69.8
19	Max	70.9	71.4	76.9	69.4	77.0	68.7	77.0	68.0	76.1	67.3	73.0	66.3
	Min	66.8	70.2	59.3	67.4	57.9	66.5	56.0	66.1	55.8	65.2	54.5	63.7
20	Max	68.7	70.0	66.3	68.0	66.1	67.8	65.9	67.5	65.3	67.0	63.8	65.5
	Min	68.0	69.4	64.3	66.8	64.0	65.3	63.1	66.2	62.8	65.9	61.5	64.9
22	Max	70.0	67.7	78.0	65.4	79.4	65.3	81.2	66.2	80.3	66.6	77.8	66.7
	Min	65.6	66.3	62.3	64.5	62.2	64.1	61.8	64.2	61.7	64.0	61.7	63.4
23	Max	69.4	66.6	72.3	66.8	73.3	86.9	75.4	67.6	74.4	67.8	71.9	67.4
	Min	68.0	66.5	64.9	66.2	64.4	66.2	64.4	66.7	64.3	66.5	63.3	66.0
24	Max	73.0	67.4	79.0	67.7	79.2	68.1	80.1	69.0	79.8	69.4	78.0	69.6
	Min	68.7	67.1	68.7	66.9	68.9	67.0	69.1	67.5	68.9	67.5	68.0	67.1
25	Max	74.9	67.8	82.6	69.3	82.6	69.9	82.4	71.0	83.6	71.6	80.8	71.9
	Min	72.2	67.5	70.6	68.8	70.2	68.9	70.0	69.2	70.0	69.2	69.2	69.2
26	Max	71.2	69.0	79.0	70.2	78.3	70.0	78.5	70.3	77.5	70.0	74.8	69.4
	Min	69.7	68.1	67.3	68.8	66.3	68.7	66.0	69.1	66.0	68.8	65.1	68.0
27	Max	71.9	67.8	84.2	68.9	83.3	68.5	83.3	68.8	82.4	69.9	77.9	67.9
	Min	67.7	67.0	64.1	67.5	63.0	67.0	61.7	67.0	61.5	66.6	60.3	65.5
29	Max	70.9	68.3	75.0	69.3	74.7	68.9	74.8	68.9	76.1	68.6	74.1	68.1
	Min	67.9	68.1	65.3	68.1	64.7	67.8	63.6	67.6	63.6	67.2	62.8	66.1
30	Max	70.0	68.2	71.2	68.0	70.2	67.4	71.5	67.8	71.3	68.2	69.5	87.8
	Min	67.3	68.0	62.5	67.0	62.0	66.2	61.5	66.3	62.0	66.1	61.0	65.2
31	Max	69.0	68.1	73.6	66.9	72.5	68.4	73.2	66.3	74.7	66.4	73.0	88.1
	Min	65.7	67.5	60.2	65.7	59.2	65.1	58.1	65.1	58.3	64.7	57.6	63.6
Monthly range		2.96	0.64	11.25	1.10	11.40	1.25	12.63	1.51	12.63	1.90	12.57	2.29

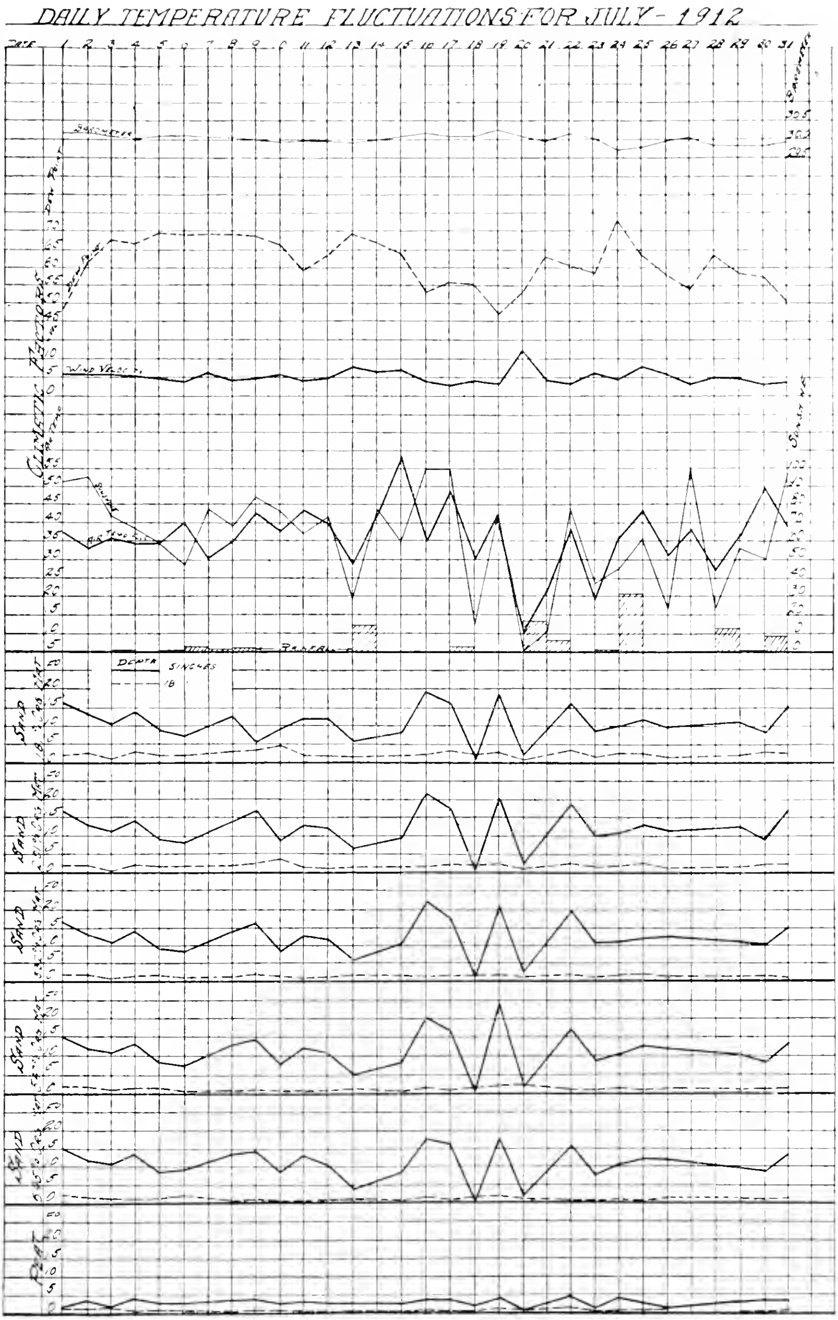
DAILY TEMPERATURE FLUCTUATIONS FOR JULY - 1912
DATE
CLIMATIC FACTORS
SAND
PEAT
RAINFALL
DEPTH INCHES

FIG. 44.

TABLE 63.—EFFECT OF ORGANIC MATTER ON TEMPERATURE OF SOILS. DAILY MAXIMUM AND MINIMUM, AUGUST, 1912.

Date	Maximum, minimum.	Peat. 5″	Peat. 18″	6.95% Org. Mat. 5″	6.95% Org. Mat. 18″	5.47% Org. Mat. 5″	5.47% Org. Mat. 18″	3.32% Org. Mat. 5″	3.32% Org. Mat. 18″	2.01% Org. Mat. 5″	2.01% Org. Mat. 18″	1.81% Org. Mat. 5″	1.81% Org. Mat. 18″
1	Max	67.6	67.3	73.4	66.0	71.6	65.4	73.3	65.6	73.4	65.9	71.1	65.4
	Min	65.0	66.2	59.8	65.0	58.7	64.3	58.3	64.5	59.0	64.4	58.2	63.6
2	Max	67.0	66.2	68.7	65.9	67.3	65.2	67.1	65.6	66.8	65.5	65.0	65.0
	Min	65.2	66.1	62.8	65.1	61.8	64.4	61.2	64.8	61.5	64.6	60.5	63.8
3	Max	64.3	65.8	67.1	64.4	66.1	63.5	66.8	63.3	66.6	63.0	64.9	62.2
	Min	62.3	65.3	56.9	63.2	55.2	62.3	54.2	62.3	54.2	61.9	53.2	61.4
5	Max	68.7	64.3	78.1	65.1	78.0	65.0	78.0	65.8	77.3	66.0	73.7	65.7
	Min	64.0	64.0	61.0	64.0	59.9	63.6	59.2	63.7	59.1	63.4	57.8	62.6
6	Max	69.4	64.5	77.3	66.1	77.4	66.2	77.2	67.0	76.8	67.1	73.7	66.4
	Min	65.9	64.5	64.6	65.8	63.7	65.3	63.0	65.4	63.0	65.1	61.5	64.2
7	Max	70.3	65.0	76.2	67.3	75.6	87.5	76.1	68.2	75.0	68.2	72.4	67.7
	Min	67.6	64.9	67.3	66.9	67.0	66.7	66.3	66.9	66.1	66.6	65.1	65.8
8	Max	71.4	65.5	78.8	67.6	78.8	67.6	78.2	68.2	77.9	68.3	75.9	68.4
	Min	68.6	65.3	67.9	67.2	67.6	67.0	67.0	67.2	66.6	66.6	65.7	66.0
9	Max	71.3	66.1	73.3	68.0	74.3	68.0	75.9	68.5	75.0	68.8	73.6	68.6
	Min	69.5	65.4	68.7	67.4	68.0	67.3	67.8	67.5	67.8	67.4	66.9	66.9
10	Max	70.1	66.6	74.4	67.8	74.1	67.6	73.4	67.6	73.8	67.2	72.0	67.1
	Min	67.9	66.0	65.3	66.5	64.8	66.2	64.0	66.2	64.1	66.0	63.2	65.8
12	Max	71.0	66.5	76.8	66.2	76.2	66.0	79.0	66.6	79.6	67.1	78.0	67.8
	Min	67.0	65.5	64.6	65.1	64.5	65.0	64.2	65.1	64.1	65.1	63.3	64.8
13	Max	73.6	66.4	81.7	67.7	81.5	67.9	83.8	69.2	83.9	70.0	81.7	70.8
	Min	70.0	65.6	69.0	66.4	68.8	66.4	69.0	67.2	69.0	67.5	68.2	67.6
14	Max	74.5	66.9	83.3	69.4	83.0	69.4	83.9	70.5	83.4	71.2	80.0	71.2
	Min	71.1	66.6	69.2	68.5	67.9	68.3	67.7	69.0	68.0	69.2	67.6	69.0
15	Max	72.0	67.7	79.8	70.1	79.6	70.0	79.4	70.2	78.0	70.1	74.8	69.1
	Min	69.3	67.4	66.0	68.4	64.7	68.3	63.6	68.5	63.5	68.2	63.0	67.2
16	Max	71.6	67.8	80.1	69.1	80.2	68.4	79.8	68.4	78.4	68.8	75.0	67.5
	Min	67.6	67.2	64.1	67.6	63.0	67.0	61.8	67.0	61.5	66.1	60.5	65.0
17	Max	69.2	67.6	73.2	68.9	73.3	68.2	73.3	68.5	73.0	68.0	71.1	66.4
	Min	68.0	67.1	66.0	67.2	65.1	67.0	64.0	67.1	63.6	66.4	62.6	65.3
19	Max	71.1	67.1	73.5	69.0	73.4	69.2	73.0	69.4	72.4	69.3	71.3	69.0
	Min	70.3	67.0	70.4	68.3	70.1	68.1	69.4	68.7	69.4	68.5	68.7	68.1
20	Max	72.2	67.4	77.0	68.3	77.8	68.2	79.0	68.7	79.5	69.0	78.2	69.2
	Min	69.5	67.0	68.0	67.4	67.5	67.3	67.4	67.5	67.3	67.2	66.1	67.0
21	Max	73.2	68.3	78.2	69.0	79.0	69.0	80.4	70.0	80.6	70.6	78.6	70.8
	Min	69.7	67.1	66.6	67.8	66.2	67.4	66.0	67.9	65.9	67.9	65.2	67.5
22	Max	71.0	68.7	72.6	69.0	74.1	69.2	76.3	69.7	76.1	69.9	73.7	69.4
	Min	69.8	68.3	66.0	68.5	66.0	68.1	65.8	68.9	65.4	68.9	64.9	68.2
23	Max	68.0	68.4	71.4	67.8	71.4	67.5	71.7	67.9	71.4	67.4	69.0	66.2
	Min	66.3	67.2	62.0	66.3	61.5	65.6	61.0	66.7	61.0	66.2	59.9	65.3
24	Max	68.1	67.5	78.4	66.0	79.4	65.9	80.0	66.0	79.6	66.2	76.3	66.0
	Min	64.3	66.2	60.1	64.8	59.8	64.3	59.4	64.8	59.6	64.3	58.4	63.2
26	Max	76.0	67.6	83.7	71.3	83.1	71.9	82.3	72.4	81.8	73.0	79.9	73.1
	Min	72.7	65.9	72.6	70.0	72.2	70.2	71.6	70.9	71.9	71.0	71.0	70.8
27	Max	72.8	69.6	80.9	72.0	80.0	71.8	78.8	71.5	78.0	71.2	75.0	70.7
	Min	70.2	68.4	66.5	70.2	65.3	70.1	64.2	70.0	63.8	69.3	62.7	68.2
28	Max	70.0	69.0	66.1	70.0	65.8	69.8	65.0	69.7	65.6	68.9	63.7	67.8
	Min	66.9	67.8	63.2	66.1	63.2	66.9	62.8	66.6	62.3	66.0	61.0	65.0
29	Max	67.7	67.6	70.8	66.3	71.0	66.0	71.1	65.8	71.7	65.4	70.5	65.1
	Min	65.4	67.3	62.0	65.4	61.8	65.3	61.0	65.3	60.7	64.9	60.0	63.8
30	Max	64.3	86.3	63.4	64.8	63.5	64.3	63.9	64.0	63.9	63.8	83.1	62.8
	Min	62.3	64.9	57.0	62.6	55.7	62.1	54.8	62.2	55.4	61.8	55.3	61.0
31	Max	69.2	64.7	80.2	63.8	80.9	64.2	82.0	65.5	81.6	66.0	78.9	66.6
	Min	62.7	64.3	60.6	62.2	61.1	61.8	61.3	62.3	61.3	62.1	60.6	61.5
Monthly range		2.82	0.63	10.73	1.22	11.29	1.37	12.34	1.49	12.07	1.85	10.77	2.15

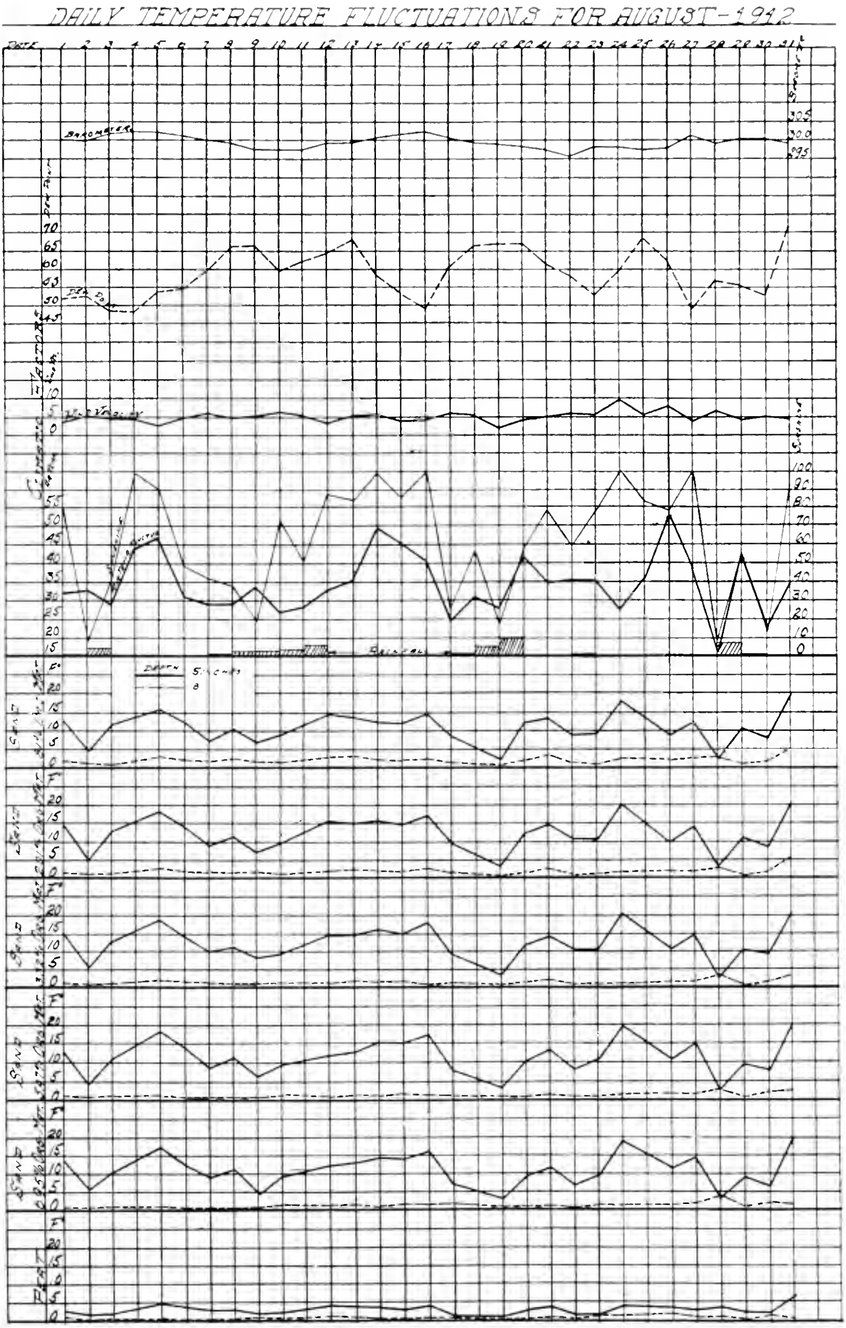
DAILY TEMPERATURE FLUCTUATIONS FOR AUGUST-1912
BAROMETER
DEW POINT
RAINFALL
DEPTH
SAND
PEAT

FIG. 45.

TABLE 64.—EFFECT OF ORGANIC MATTER ON TEMPERATURE OF SOILS. DAILY MAXIMUM AND MINIMUM, SEPTEMBER, 1912.

Date	Maximum, minimum.	Peat.		6.95% Org. Mat.		5.47% Org. Mat.		3.32% Org. Mat.		2.01% Org. Mat.		1.81% Org. Mat.	
		5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″
2	Max	76.0	66.2	84.6	69.9	85.1	70.7	84.9	71.8	84.1	72.1	81.9	72.6
	Min	71.5	65.8	72.2	68.7	72.0	69.0	72.0	69.6	72.0	69.7	71.4	69.7
3	Max	75.9	67.1	84.0	70.5	34.1	70.9	83.5	71.5	82.8	72.0	80.0	72.0
	Min	72.3	66.6	70.9	70.0	69.8	70.0	68.8	70.3	68.8	70.1	68.2	70.0
4	Max	75.2	69.0	82.2	71.6	82.8	71.5	82.8	71.6	81.8	71.7	79.4	71.7
	Min	72.7	68.3	70.9	70.8	70.0	71.0	69.0	70.8	69.0	70.8	68.0	69.9
5	Max	76.1	69.4	80.6	71.4	82.3	71.8	84.0	72.5	82.6	72.6	79.3	72.6
	Min	72.8	69.3	70.4	70.4	70.0	70.4	69.4	70.6	69.2	70.3	68.1	70.0
6	Max	76.0	69.7	84.2	71.4	84.7	71.4	84.3	72.4	84.0	72.8	83.4	73.1
	Min.	72.8	69.5	69.7	70.7	69.4	70.6	68.8	70.8	68.8	70.4	68.0	70.1
7	Max	76.3	70.1	85.2	72.0	85.8	72.2	84.6	72.2	83.6	72.7	81.9	73.0
	Min	73.0	69.9	70.2	71.4	69.3	71.3	68.0	71.3	68.7	71.3	68.5	71.2
9	Max	75.8	70.0	85.7	72.1	86.5	72.7	86.6	72.7	85.7	72.7	83.2	72.6
	Min	72.0	69.3	71.0	70.8	70.4	70.8	69.3	71.0	69.3	70.8	68.7	70.1
10	Max	76.0	70.4	85.4	73.0	86.2	74.0	86.2	73.6	85.5	74.0	83.2	73.8
	Min	73.0	70.1	70.9	72.3	70.0	72.3	68.8	72.0	69.0	72.1	68.0	71.5
11	Max	74.2	71.0	75.0	73.3	75.3	73.4	75.1	73.6	74.9	73.1	73.6	72.4
	Min..	72.1	70.9	71.3	72.5	70.3	72.4	69.3	72.5	69.4	72.1	68.8	71.4
12	Max	70.1	70.8	73.0	70.0	73.3	69.7	73.9	69.4	73.9	69.0	73.7	68.6
	Min	67.0	70.2	59.2	68.4	58.3	68.1	57.0	67.7	57.8	67.2	57.2	66.0
13	Max	68.4	69.6	73.0	67.9	73.1	67.5	74.8	67.7	75.0	68.1	73.0	67.7
	Min	66.0	69.1	60.2	66.9	69.1	66.8	59.2	66.8	60.3	66.7	59.4	65.7
14	Max	67.7	68.2	70.0	67.2	70.4	67.0	70.5	67.7	70.3	67.8	69.0	67.0
	Min	66.1	67.7	64.5	66.1	64.2	66.0	64.4	66.5	65.0	66.2	64.2	65.5
16	Max	67.5	67.0	71.3	66.2	71.8	66.0	71.2	65.8	71.5	65.7	70.0	65.4
	Min.	64.4	66.7	58.5	65.1	57.8	64.7	56.1	64.7	56.6	64.1	56.1	63.2
17	Max	65.1	66.7	62.7	65.7	62.4	65.4	62.1	65.3	62.0	65.0	61.5	64.4
	Min	63.1	66.2	60.1	64.2	59.4	64.0	58.4	64.0	59.0	63.6	58.2	62.8
18	Max	64.8	65.8	66.5	63.8	66.4	63.7	67.0	63.9	66.4	64.0	65.4	63.6
	Min..	63.1	65.0	61.4	63.4	61.4	63.3	61.1	63.3	61.1	63.2	60.5	62.4
19	Max	62.0	65.1	60.3	63.7	59.9	63.6	60.3	63.3	60.6	63.0	58.9	61.7
	Min	60.7	64.8	55.6	62.4	55.1	62.1	54.4	62.2	54.6	61.9	54.2	60.6
20	Max	61.1	64.2	64.4	61.7	64.6	61.1	65.2	61.4	65.4	61.3	63.9	60.8
	Min	59.0	62.8	55.1	60.8	54.5	60.5	54.5	60.4	54.3	59.8	53.6	59.1
21	Max	63.3	63.3	67.4	62.2	67.6	61.9	69.4	63.0	70.2	63.4	68.7	63.3
	Min	60.2	62.5	57.8	60.9	58.2	61.2	58.0	61.4	57.9	60.9	57.5	60.6
23	Max	62.1	63.4	66.4	62.2	67.3	61.6	68.3	62.1	67.9	62.0	65.6	61.7
	Min	57.3	62.2	52.5	60.4	52.3	59.7	50.6	59.8	51.1	59.4	51.3	58.1
24	Max	60.4	61.6	64.6	61.0	65.5	60.5	65.2	60.6	65.8	60.4	64.7	59.9
	Min.	58.3	61.2	54.5	60.2	54.6	59.5	54.1	59.8	54.5	59.4	53.7	58.6
25	Max	61.9	61.6	68.2	60.9	69.3	61.3	70.5	61.8	69.8	61.6	71.7	61.3
	Min	61.2	61.0	59.4	60.6	59.6	60.7	59.4	61.3	59.6	61.1	59.2	60.6
26	Max	62.2	62.1	62.1	62.6	61.4	62.8	61.4	63.2	62.2	63.3	60.9	62.8
	Min	60.6	61.5	57.3	61.6	56.0	61.1	55.1	61.9	56.6	61.8	56.7	60.9
27	Max	56.1	62.6	58.0	60.2	58.1	59.7	59.5	59.4	58.5	59.0	55.9	57.5
	Min	53.6	61.8	47.0	57.4	46.0	57.5	45.3	57.3	45.5	56.7	45.1	55.1
28	Max	54.4	60.3	52.3	57.0	52.1	57.5	52.2	57.3	52.5	57.2	51.5	55.3
	Min	53.7	59.9	50.4	56.9	49.9	56.8	49.0	56.7	49.3	56.8	48.7	54.8
30	Max	52.9	57.5	53.9	54.8	53.8	54.8	54.4	53.9	55.0	53.6	54.1	53.6
	Min.	50.7	57.4	44.9	54.5	44.3	54.0	43.2	53.7	43.8	53.0	42.9	51.5
Monthly range		2.55	0.58	9.80	1.00	10.65	0.43	11.80	1.25	11.23	1.56	10.31	1.97

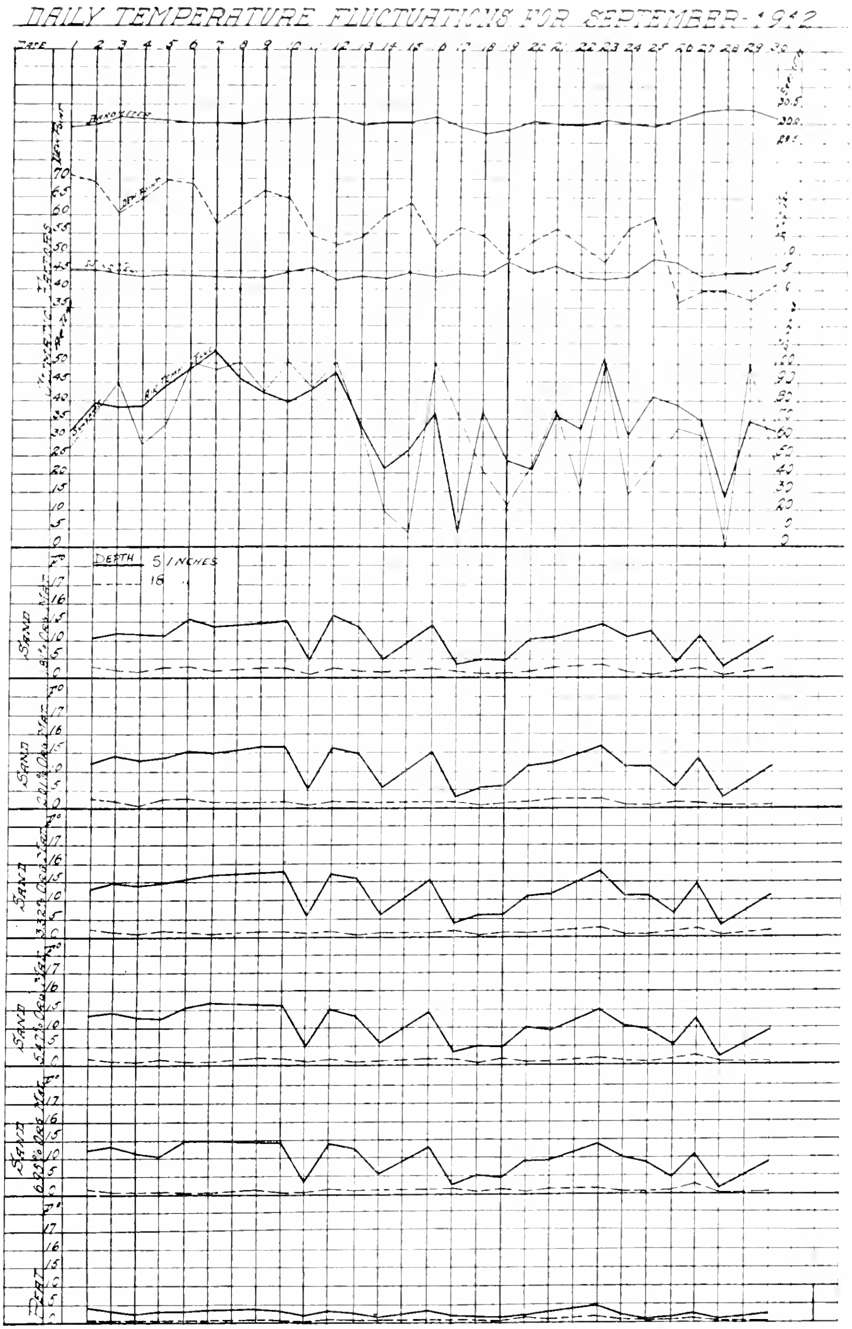
DAILY TEMPERATURE FLUCTUATIONS FOR SEPTEMBER-1912
BAROMETER
DEW POINT
AIR TEMP
DEPTH 5 INCHES
18
SAND
PEAT

FIG. 46.

TABLE 65. EFFECT OF ORGANIC MATTER ON TEMPERATURE OF SOILS. DAILY MAXIMUM AND MINIMUM, OCTOBER, 1912.

Date	Maximum, minimum.	Peat. 5″	Peat. 18″	6.95% Org. Mat. 5″	6.95% Org. Mat. 18″	5.47% Org. Mat. 5″	5.47% Org. Mat. 18″	3.32% Org. Mat. 5″	3.32% Org. Mat. 18″	2.01% Org. Mat. 5″	2.01% Org. Mat. 18″	1.81% Org. Mat. 5″	1.81% Org. Mat. 18″
1	Max	54.3	57.5	60.4	54.6	60.6	54.9	60.2	55.3	60.3	55.2	58.9	54.8
	Min	50.4	56.6	45.6	54.3	45.0	53.6	44.3	53.7	44.8	53.2	44.3	51.9
2	Max	53.6	56.3	61.1	55.3	61.3	54.8	62.0	55.6	62.1	55.4	60.4	55.1
	Min	50.5	56.2	45.8	54.7	45.3	54.2	44.0	54.2	44.6	53.7	44.3	52.3
3	Max	52.7	56.7	54.8	55.8	54.8	55.6	54.9	55.8	54.8	55.4	54.0	54.6
	Min	51.8	56.0	50.0	55.3	49.9	55.0	50.2	55.0	50.3	54.6	49.6	53.7
4	Max	57.0	55.9	61.9	55.8	62.2	55.5	62.7	56.8	61.9	56.9	60.4	56.6
	Min	52.8	55.5	50.0	55.0	49.7	55.0	49.2	55.4	49.3	54.7	48.9	53.8
5	Max	57.2	56.0	64.3	56.5	64.7	56.9	65.8	57.4	64.9	58.2	63.4	58.1
	Min	53.3	55.7	48.8	55.9	47.3	55.7	47.8	55.3	47.2	54.5	47.7	54.5
7	Max	58.8	56.6	62.2	59.3	61.0	59.4	61.7	60.0	61.5	60.0	59.9	59.9
	Min	57.5	56.0	57.9	58.4	57.4	58.6	56.8	58.9	57.4	58.9	57.3	58.4
8	Max	53.4	56.7	53.4	57.4	53.8	57.5	54.4	57.0	54.0	56.2	52.1	54.9
	Min	52.2	56.4	47.0	56.3	45.9	56.4	44.8	54.5	45.0	53.8	44.4	52.9
9	Max	53.8	55.6	56.3	54.2	56.7	54.1	56.4	54.2	56.2	54.0	55.2	53.6
	Min	50.8	55.2	49.3	53.8	49.2	53.0	49.0	53.2	48.7	52.9	48.0	51.8
10	Max	54.6	55.8	54.7	55.4	54.8	55.3	54.9	55.4	54.5	55.1	53.9	54.5
	Min	53.8	55.5	53.2	55.0	52.8	54.9	52.7	54.8	52.8	54.6	51.9	54.0
11	Max	57.1	55.7	60.1	55.3	59.9	55.8	59.8	56.3	59.5	56.0	58.8	56.2
	Min	54.5	55.4	54.1	54.8	53.9	54.5	53.4	55.0	53.8	54.8	52.0	54.2
12	Max	58.2	56.0	56.7	57.0	56.1	57.3	55.0	57.4	55.1	57.2	54.8	56.8
	Min	55.6	55.4	54.2	56.5	53.4	55.8	52.8	55.7	52.5	55.7	51.7	55.1
14	Max	48.6	56.1	50.8	53.1	52.4	52.9	54.0	52.4	53.7	51.6	52.9	50.7
	Min	48.5	53.4	50.0	50.6	51.1	50.4	50.7	51.0	51.0	50.9	50.8	50.5
15	Max	50.4	54.0	51.6	52.1	52.8	51.8	54.0	52.1	53.3	51.6	51.7	50.6
	Min	47.4	53.8	43.5	51.7	43.5	50.5	42.5	50.8	42.7	50.6	42.4	49.5
16	Max	47.9	53.2	53.8	51.6	53.4	51.1	52.9	50.8	53.1	50.7	51.4	49.6
	Min	44.9	52.4	40.0	50.1	39.5	49.5	37.6	49.0	37.9	48.6	37.2	47.1
17	Max	49.4	52.3	55.9	50.9	56.1	51.3	56.4	51.8	55.7	51.5	54.7	51.1
	Min	45.9	52.1	42.5	50.3	43.5	50.1	41.9	50.0	42.1	49.5	41.3	48.0
18	Max	52.4	51.9	57.4	52.9	58.0	53.2	59.8	53.9	58.6	54.1	57.4	53.6
	Min	49.5	51.0	51.3	51.3	51.6	51.5	52.5	51.8	51.5	51.6	51.0	51.0
19	Max	51.8	52.1	50.6	52.7	50.5	53.0	51.8	53.9	51.8	53.3	50.7	52.9
	Min	48.9	51.2	47.5	50.4	47.0	51.4	45.0	51.0	45.4	51.0	45.1	50.3
21	Max	50.9	52.9	56.7	51.8	57.3	51.3	57.4	51.9	56.9	51.9	56.4	51.4
	Min	47.5	52.4	44.6	50.6	44.0	50.5	42.9	50.2	42.9	49.7	42.4	48.6
22	Max	54.0	52.1	54.2	56.7	57.0	54.4	57.4	54.8	57.4	54.7	56.8	54.5
	Min	51.7	51.3	52.1	54.0	53.4	52.5	52.0	53.4	52.1	52.7	51.7	52.3
23	Max	49.2	52.3	45.6	51.5	44.3	51.1	43.9	51.0	43.9	50.2	43.5	49.9
	Min	47.4	50.4	44.6	50.3	43.9	49.2	42.4	49.0	42.8	48.8	42.7	47.7
24	Max	46.2	52.6	47.9	50.3	46.9	49.6	47.2	49.4	46.5	48.3	45.7	47.3
	Min	45.3	52.2	39.5	49.3	38.2	48.9	36.7	48.3	37.0	47.9	37.0	46.0
25	Max	46.5	51.8	49.8	48.9	49.9	48.1	50.0	48.1	50.8	48.1	50.0	47.7
	Min	44.7	51.3	38.3	48.1	37.3	47.2	36.4	46.9	36.5	46.3	36.3	45.0
26	Max	46.7	51.0	50.0	48.8	49.8	48.6	51.7	48.4	51.1	48.5	49.4	47.8
	Min	44.2	50.5	39.6	48.2	38.8	47.6	37.7	47.4	37.9	46.9	37.7	46.0
28	Max	47.9	49.6	53.8	48.9	53.5	48.9	53.4	49.3	53.6	49.4	52.5	49.0
	Min	44.2	49.0	42.6	47.9	42.0	47.5	41.3	47.4	44.8	47.0	41.2	45.9
29	Max	49.0	49.8	53.2	50.0	53.5	50.1	54.9	50.7	54.8	50.7	53.0	50.4
	Min	47.2	49.4	45.4	49.7	45.2	49.5	45.0	49.7	45.3	49.5	45.1	48.8
30	Max	48.5	49.6	44.9	49.9	44.4	49.9	44.0	49.8	44.0	49.4	42.9	48.7
	Min	46.3	49.3	44.2	49.1	43.8	48.9	42.6	48.9	42.8	48.3	42.4	47.5
31	Max	44.9	49.6	40.4	48.0	40.3	47.8	39.8	47.4	39.8	48.8	38.9	44.8
	Min	42.3	49.4	38.3	46.8	37.8	46.1	36.1	45.8	35.9	45.0	35.2	43.5
Monthly range		2.41	0.60	7.51	0.97	7.99	1.18	9.19	1.53	8.78	1.63	8.14	2.0

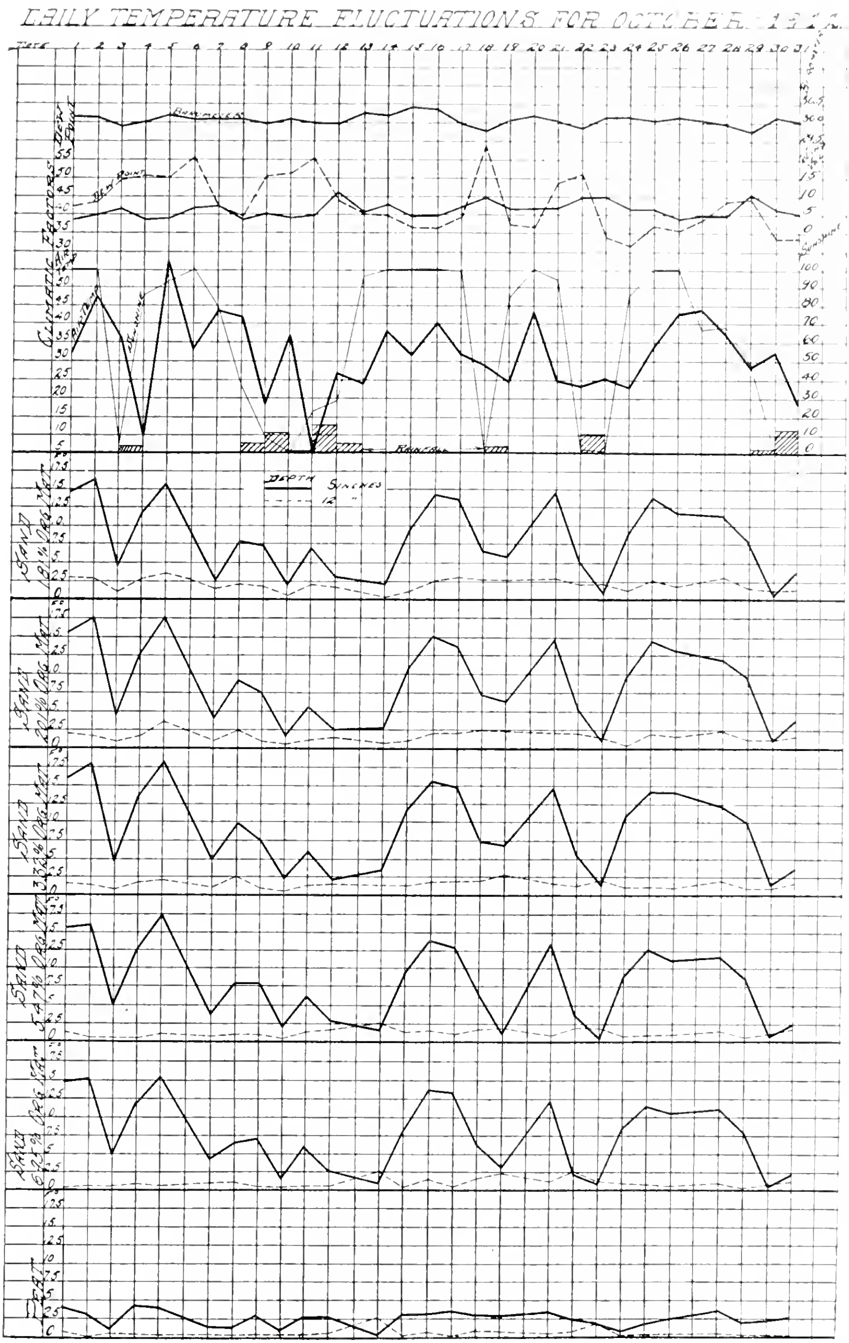
DAILY TEMPERATURE FLUCTUATIONS FOR OCTOBER 1912.
DATE
CLIMATIC FACTORS
DEW POINT
BAROMETER
AIR TEMP.
SUNSHINE
RAINFALL
DEPTH 5 INCHES
12 "
SAND 81% ORG. MAT.
SAND 70% ORG. MAT.
SAND 33% ORG. MAT.
SAND 54% ORG. MAT.
SAND 62% ORG. MAT.
PEAT

FIG. 47.

TABLE 66.—EFFECT OF ORGANIC MATTER ON TEMPERATURE OF SOILS. DAILY MAXIMUM AND MINIMUM, NOVEMBER, 1912.

Date—Maximum, minimum.	Peat.		6.95% Org. Mat.		5.47% Org. Mat.		3.32% Org. Mat.		2.01% Org. Mat.		1.81% Org. Mat.	
	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″
1 Max	41.0	49.1	37.1	45.8	36.2	44.8	35.3	44.4	35.4	43.9	34.8	42.2
Min	39.5	48.6	35.9	44.4	35.4	43.7	34.9	43.0	34.9	42.5	34.4	41.1
2 Max	38.5	47.9	35.8	43.1	35.1	42.8	34.3	42.4	34.6	41.7	33.7	39.9
Min	38.2	47.1	35.1	42.7	34.7	42.2	33.6	41.8	33.4	40.9	32.9	39.2
4 Max	37.0	45.0	40.4	42.5	40.9	42.1	41.1	42.0	41.5	41.7	40.9	40.9
Min	36.8	44.5	35.9	42.3	35.3	42.0	34.9	41.7	34.8	40.8	33.8	39.3
5 Max	41.8	44.6	47.2	43.9	47.9	44.1	48.8	44.5	48.6	44.3	47.9	44.2
Min	39.1	43.9	39.9	43.4	39.8	43.3	39.4	43.4	39.2	42.9	38.9	42.2
6 Max	47.1	44.8	49.5	47.1	49.9	47.4	49.5	48.1	49.4	48.1	49.1	47.9
Min	44.8	44.2	47.9	45.9	48.3	46.4	48.3	46.9	48.3	46.8	47.8	46.6
7 Max	46.3	45.8	46.8	47.8	47.0	47.9	47.0	47.9	46.9	47.6	45.4	47.8
Min	45.0	45.2	44.0	47.3	43.7	47.2	42.2	47.4	42.5	47.2	41.8	46.4
8 Max	43.3	46.2	44.2	46.3	44.1	45.7	44.4	45.7	44.3	45.7	43.1	45.0
Min	42.0	45.9	39.4	45.7	38.6	45.3	38.0	44.8	38.1	44.2	37.3	43.0
9 Max	42.7	46.4	43.0	45.8	43.0	45.7	43.8	45.3	43.4	45.0	42.4	44.2
Min	42.2	46.0	40.0	45.2	39.9	45.1	39.2	45.1	39.1	44.8	38.4	43.8
10 Max	45.2	45.7	51.3	45.7	51.8	46.1	52.8	46.7	52.5	46.8	51.8	46.6
Min	42.7	45.1	42.5	45.0	41.8	45.0	42.0	44.9	42.0	44.6	41.4	43.0
12 Max	49.5	46.2	53.1	48.9	53.2	48.9	53.7	49.7	53.5	49.6	52.8	49.6
Min	47.5	45.8	49.7	48.0	49.7	48.1	49.9	48.4	49.7	48.3	49.2	48.1
13 Max	51.0	48.3	52.3	50.7	52.3	51.0	52.2	51.2	52.3	51.3	51.7	51.1
Min	50.1	46.9	47.4	49.7	46.3	49.9	45.1	50.4	45.0	50.3	44.4	50.0
14 Max	44.9	48.5	39.6	48.0	38.9	47.8	37.5	47.3	37.8	46.8	37.0	45.4
Min	42.9	48.0	38.0	46.7	37.4	46.1	36.4	45.8	36.4	45.8	35.6	43.8
15 Max	41.2	48.1	38.4	45.0	37.4	44.4	36.7	44.2	36.4	43.3	35.0	41.8
Main	40.0	47.8	35.9	44.2	35.4	43.8	34.1	43.4	34.1	42.5	32.9	41.2
16 Max	38.9	47.1	35.8	43.7	35.0	42.9	33.7	42.8	33.7	42.0	32.2	40.2
Min	37.8	45.8	34.2	42.2	33.5	41.6	32.8	41.3	32.5	40.3	31.2	38.7
17 Max	37.8	43.8	39.9	42.1	39.9	42.0	39.1	42.0	39.4	41.4	38.6	40.6
Min	37.3	43.0	36.1	41.9	35.7	41.6	34.2	41.3	34.0	40.4	33.0	39.0
19 Max	39.0	43.4	42.6	42.2	42.8	42.0	42.7	42.6	42.7	42.1	42.1	41.8
Min	37.6	43.2	36.4	41.9	36.2	41.7	35.0	41.5	34.9	41.0	34.1	39.7
20 Max	39.1	43.1	42.5	42.6	42.7	42.4	42.7	42.3	42.8	42.1	42.2	41.8
Min	38.1	43.0	36.5	42.2	36.2	42.0	36.4	41.7	35.9	41.0	34.0	39.7
21 Max	40.5	42.5	43.3	42.8	44.5	42.8	45.6	43.2	45.8	43.0	45.0	42.5
Min	39.6	42.0	40.5	42.4	40.8	42.2	40.3	42.6	40.5	42.3	40.0	41.9
22 Max	39.3	43.0	39.3	43.0	39.4	42.9	39.9	42.6	39.8	41.9	39.3	40.5
Min	38.8	42.8	36.3	42.8	36.0	42.6	35.6	42.3	35.6	41.4	34.6	40.0
25 Max	37.0	42.5	35.2	40.8	34.9	40.5	34.2	40.1	34.2	39.3	33.2	38.3
Min	36.7	42.5	34.0	40.0	33.9	40.0	33.0	38.7	32.9	38.2	32.0	36.8
26 Max	36.1	41.9	34.1	39.5	34.1	39.3	33.4	39.0	33.1	38.3	32.0	37.3
Min	36.0	41.6	34.0	39.4	34.0	39.2	33.2	38.9	32.9	38.1	32.0	37.1
27 Max	35.8	41.4	34.2	39.2	34.2	39.1	34.0	38.7	33.2	38.2	32.2	36.8
Min	35.6	41.3	34.2	39.0	34.0	39.0	33.6	38.6	33.1	37.9	32.2	36.8
29 Max	36.1	41.8	34.8	39.6	34.6	39.2	34.0	39.1	33.8	38.5	33.0	37.3
Min	35.9	41.5	34.7	39.4	34.5	39.1	34.0	39.0	33.8	38.3	32.9	37.3
30 Max	35.8	41.2	34.5	39.3	34.2	39.1	33.4	38.9	33.4	38.3	32.4	37.2
Min	35.2	40.7	34.0	38.8	33.5	38.5	33.0	38.3	32.8	37.8	31.6	36.4
Monthly range	1.06	0.50	3.01	0.41	3.31	0.99	3.78	1.09	3.83	0.95	3.81	1.25

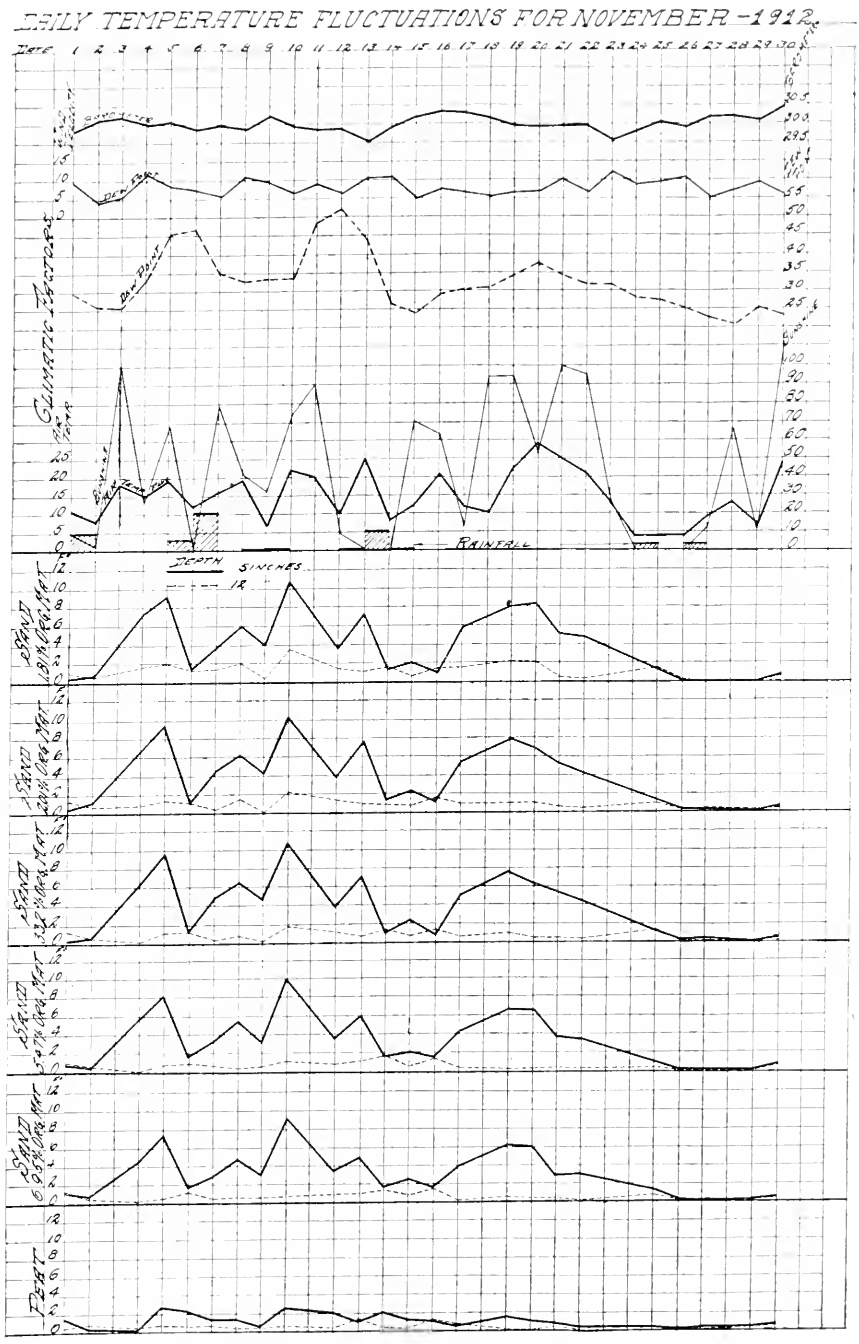
TEMPERATURE FLUCTUATIONS FOR NOVEMBER -1912
DATE
CLIMATIC FACTORS
DEW POINT
RAINFALL
DEPTH
INCHES
SAND
PEAT

FIG. 48.

TABLE 67. EFFECT OF ORGANIC MATTER ON TEMPERATURE OF SOILS. DAILY MAXIMUM AND MINIMUM, DECEMBER, 1912.

Date	Maximum, minimum.	Peat.		6.95% Org. Mat.		5.47% Org. Mat.		3.32% Org. Mat.		2.01% Org. Mat.		1.81% Org. Mat.	
		5"	18"	5"	18"	5"	18"	5"	18"	5"	18"	5"	18"
2	Max	40.5	40.3	44.8	42.2	45.9	42.6	47.1	43.0	47.0	43.0	46.4	42.6
	Min	38.4	40.1	41.1	40.2	40.4	40.6	38.7	41.7	38.9	41.6	38.1	41.4
3	Max	38.3	41.0	37.0	41.9	36.6	41.8	35.5	41.4	35.5	40.8	34.6	39.6
	Min	37.5	40.8	36.2	41.1	36.0	40.6	35.0	40.3	35.0	39.6	34.0	38.4
4	Max	37.5	40.9	39.6	40.1	39.3	39.9	40.2	40.1	40.0	39.9	39.1	39.4
	Min	36.6	40.2	37.0	39.9	37.0	39.8	36.8	39.8	36.6	39.4	36.0	38.4
5	Max	37.8	40.8	42.7	40.2	43.8	40.3	44.4	40.5	44.3	40.3	43.6	39.7
	Min	36.5	40.2	35.5	39.9	35.3	39.7	35.0	39.5	34.8	39.0	33.5	38.0
6	Max	41.6	41.0	43.0	42.6	42.7	42.8	41.4	43.2	41.5	43.2	40.9	43.1
	Min	39.6	40.9	37.7	42.1	37.0	42.0	36.0	41.9	35.8	41.5	34.9	40.4
7	Max	37.7	41.3	35.5	40.9	35.0	40.6	33.9	40.2	33.8	39.5	32.8	38.4
	Min	36.9	40.9	34.9	40.0	34.3	39.6	33.4	39.4	33.3	38.7	32.5	37.5
9	Max	35.0	40.6	33.1	38.5	32.9	38.3	31.7	38.1	31.4	37.2	30.3	35.8
	Min	34.6	40.3	33.1	38.2	32.6	37.9	31.2	37.7	30.8	36.9	29.5	35.6
10	Max	34.4	40.0	32.8	37.7	32.4	37.4	32.0	37.2	31.8	36.4	31.1	35.3
	Min	33.7	39.2	31.9	37.1	31.5	36.8	30.7	36.7	30.4	36.2	29.3	34.9
11	Max	34.5	39.8	33.2	37.9	32.9	37.7	32.1	37.6	31.9	36.8	31.1	35.8
	Min	33.4	38.9	32.2	37.1	31.6	36.7	30.4	36.6	30.4	35.9	29.2	34.8
12	Max	33.5	38.9	31.3	37.1	29.4	36.5	27.3	36.4	26.9	35.9	25.7	34.3
	Min	33.1	38.4	30.6	36.4	29.0	36.3	26.4	35.9	26.1	35.0	24.4	33.6
13	Max	32.8	38.4	30.8	36.2	30.7	35.9	30.5	35.5	30.8	34.8	29.8	33.3
	Min	32.6	37.9	29.5	35.8	28.0	35.5	26.3	35.2	26.1	34.3	24.9	33.1
14	Max	32.8	37.8	31.2	35.9	31.2	35.7	31.3	35.4	31.4	34.7	30.8	33.2
	Min	31.6	36.7	29.5	34.9	28.4	34.6	26.6	34.3	26.5	33.5	25.2	31.9
16	Max	32.3	36.8	31.4	35.2	31.5	35.0	31.4	35.0	31.3	34.4	31.4	33.2
	Min	32.0	36.7	31.3	35.0	31.3	34.8	31.3	34.9	31.2	34.3	30.5	33.1
17	Max	32.5	36.9	31.7	35.5	31.9	35.2	32.1	35.3	32.8	35.0	34.1	34.3
	Min	32.2	36.7	31.3	35.2	31.6	35.0	31.6	35.0	31.4	34.8	30.7	33.4
18	Max	33.1	37.4	32.4	36.2	32.7	35.9	32.7	36.0	33.6	35.9	32.8	35.0
	Min	32.9	37.2	32.2	35.9	32.4	35.7	32.4	35.9	32.8	35.7	32.1	34.9
19	Max	33.2	37.3	32.4	36.4	32.8	36.2	33.0	36.4	33.0	35.9	32.0	35.1
	Min	33.0	37.0	32.2	35.9	32.3	35.9	32.9	36.1	32.9	35.8	32.0	34.9
20	Max	33.1	37.3	32.4	36.1	32.6	36.0	32.8	36.2	32.7	35.6	31.5	34.8
	Min	32.9	36.9	32.1	35.8	32.2	35.6	32.6	35.9	32.3	35.5	31.2	34.5
21	Max	33.1	37.1	32.7	36.0	32.9	36.1	32.9	36.3	32.8	35.8	31.6	34.8
	Min	33.0	36.9	32.5	35.9	32.7	35.9	32.7	36.2	32.7	35.7	31.6	34.6
23	Max	32.9	36.8	32.4	35.9	31.9	35.9	31.6	35.9	30.9	35.6	30.1	34.3
	Min	31.9	35.9	31.3	35.0	31.2	35.0	31.1	35.1	30.5	34.5	29.2	33.2
24	Max	32.1	36.0	31.3	35.2	31.4	35.0	31.2	35.0	31.1	34.7	30.2	33.4
	Min	31.9	35.8	31.1	35.0	31.1	34.9	31.0	34.9	30.7	34.1	29.7	33.0
26	Max	32.7	36.4	31.8	35.6	31.9	35.4	31.8	35.3	31.8	35.0	30.9	33.8
	Min	32.3	36.2	31.1	35.2	30.5	35.0	29.8	35.1	28.9	34.6	27.3	33.2
27	Max	32.9	36.8	32.4	35.9	32.7	35.8	32.3	35.9	32.2	35.2	31.4	34.2
	Min	32.6	36.4	32.0	35.7	31.9	35.4	32.1	35.5	32.1	35.1	30.9	34.2
28	Max	32.9	36.6	31.4	35.9	31.3	35.7	31.2	35.8	31.2	35.0	30.5	34.0
	Min	32.1	36.0	31.3	35.0	30.4	35.0	29.8	34.9	28.1	34.1	26.1	33.1
30	Max	33.2	36.4	32.2	35.7	32.3	35.5	32.4	35.4	32.2	35.0	31.3	33.9
	Min	32.4	36.1	31.8	35.2	31.9	35.0	32.1	35.0	31.8	34.7	31.0	33.3
31	Max	32.2	36.0	32.0	35.1	32.0	35.0	31.9	35.0	31.8	34.7	31.1	33.8
	Min	31.4	35.5	31.2	34.4	31.4	34.2	31.2	34.3	31.2	33.9	30.4	32.9
Monthly range		0.70	0.43	1.24	0.56	1.55	0.59	1.91	0.57	2.08	0.63	2.43	0.74

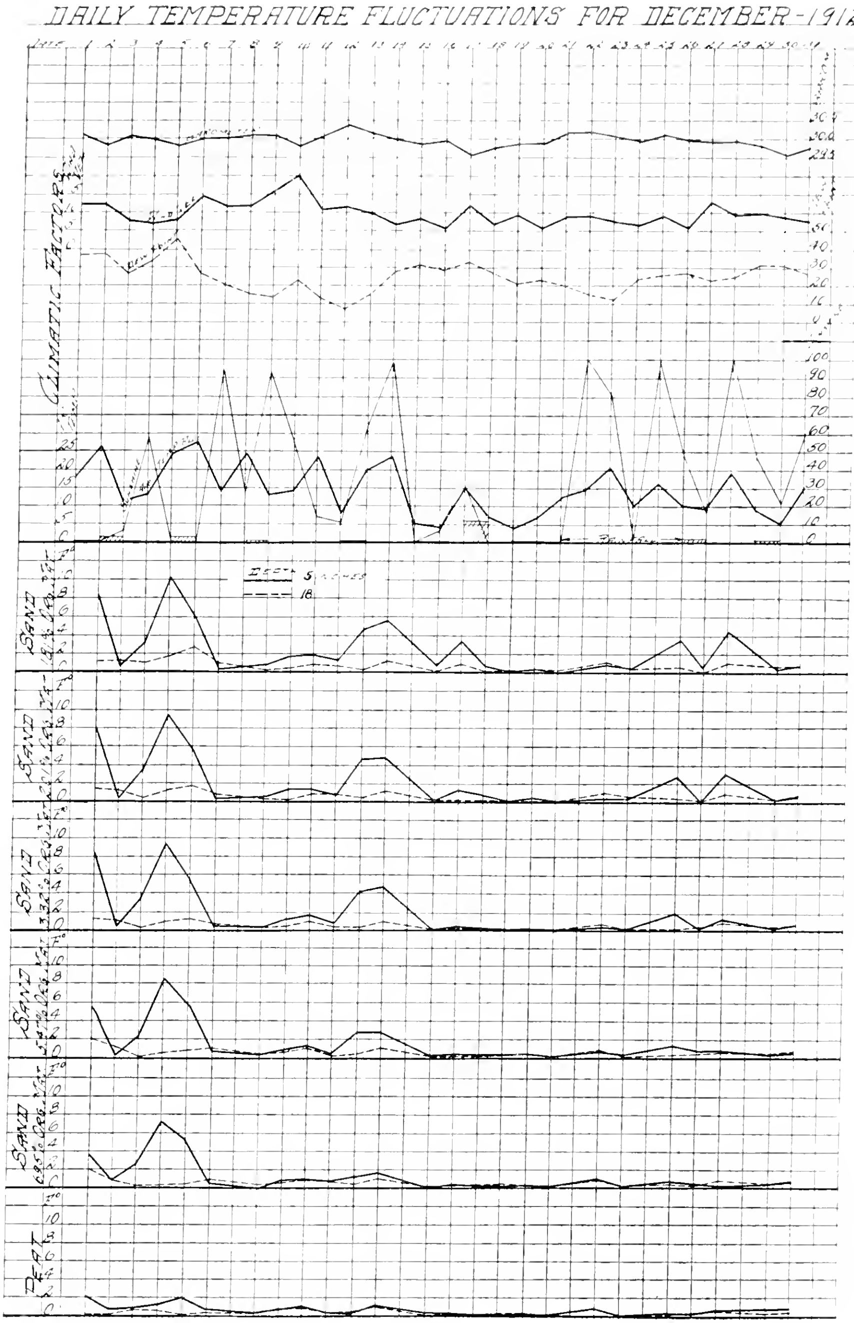
DAILY TEMPERATURE FLUCTUATIONS FOR DECEMBER-1912.
CLIMATIC FACTORS
SAND
SAND
SAND
SAND
SAND
PEAT

FIG. 49.

TABLE 68.—EFFECT OF ORGANIC MATTER ON TEMPERATURE OF SOILS. DAILY MAXIMUM AND MINIMUM, JANUARY, 1913.

Date—Maximum, minimum.		Peat.		6.95% Peat.		5.47% Peat.		3.32% Peat.		2.01% Peat.		1.81% Peat.	
		5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″
1	Max	31.9	35.7	31.7	34.9	31.6	34.9	31.6	35.0	31.5	34.3	30.8	33.3
	Min	31.7	35.6	31.2	34.6	31.6	34.5	31.3	34.6	31.2	34.0	30.3	33.1
2	Max	31.9	35.7	31.6	34.9	31.8	34.9	31.6	34.9	31.6	34.3	30.9	33.4
	Min	31.7	35.3	31.3	34.7	31.6	34.7	31.2	34.7	31.3	34.1	30.4	33.2
3	Max	32.6	36.0	32.1	35.3	32.3	35.3	32.2	35.5	32.2	34.9	31.1	34.0
	Min	32.1	35.8	31.7	35.0	31.8	35.0	31.9	35.0	31.6	34.5	30.9	33.5
4	Max	32.6	36.0	32.2	35.3	32.0	35.2	32.0	35.4	31.8	34.9	31.3	34.0
	Min	32.2	35.8	31.9	35.0	31.9	35.0	31.8	35.0	31.6	34.8	31.0	33.7
6	Max	31.9	36.0	31.7	35.1	31.6	34.9	31.9	34.9	31.7	34.3	31.0	33.2
	Min	31.3	35.3	31.1	34.3	31.2	34.1	31.0	34.0	30.9	32.8	29.9	32.2
7	Max	32.9	36.5	32.2	35.6	32.1	35.7	31.9	35.6	31.9	35.0	31.0	34.1
	Min	32.3	36.2	31.9	35.2	31.9	35.1	31.7	35.1	31.8	34.7	30.4	33.7
8	Max	32.8	36.4	32.6	35.7	32.3	35.3	32.3	35.3	32.1	34.9	31.1	34.0
	Min	32.8	36.4	32.6	35.7	32.3	35.3	32.3	35.3	32.1	34.9	31.1	34.0
9	Max	32.0	35.4	31.4	34.7	31.2	34.7	31.1	34.7	31.1	34.2	30.1	33.3
	Min	31.7	35.2	31.3	34.4	31.1	34.3	31.0	34.5	30.9	34.0	29.7	33.0
10	Max	32.3	35.9	31.8	35.1	31.5	34.9	31.4	34.9	31.3	34.6	30.7	33.7
	Min	32.1	35.7	31.6	34.9	31.4	34.8	31.3	34.7	31.3	34.1	30.1	33.2
11	Max	32.1	35.7	32.0	34.9	32.1	34.7	32.1	34.7	31.8	34.4	31.2	33.3
	Min	32.0	35.6	31.9	34.7	31.9	34.5	32.0	34.5	31.7	34.1	31.0	33.2
13	Max	32.5	35.9	32.6	35.1	32.5	35.2	32.5	34.9	32.4	34.9	30.1	33.8
	Min	32.3	35.7	32.3	34.9	32.3	35.0	32.4	34.9	32.2	34.7	29.1	33.7
14	Max	32.6	36.0	32.8	35.2	32.5	35.1	32.4	35.1	32.4	34.8	30.6	33.8
	Min	31.9	35.6	32.1	34.8	31.8	34.8	31.9	34.9	31.6	34.2	29.9	33.0
15	Max	32.4	36.0	32.8	35.2	32.3	35.2	32.4	35.2	32.3	34.7	31.2	33.7
	Min	32.0	35.6	32.1	34.8	31.8	34.9	32.0	34.9	31.4	34.3	30.1	33.2
16	Max	32.3	35.9	32.4	35.2	32.4	35.1	32.5	35.1	32.3	34.0	31.8	33.5
	Min	32.2	35.7	32.3	35.1	32.2	34.9	32.0	34.6	31.9	33.8	31.3	33.2
17	Max	32.3	35.9	32.4	35.3	32.5	34.9	32.4	34.8	32.7	34.6	32.6	33.8
	Min	32.2	35.6	32.2	35.2	32.2	34.8	32.2	34.8	32.2	33.9	31.9	33.2
18	Max	32.3	35.8	32.6	35.2	32.7	34.9	32.7	34.8	32.6	34.2	31.9	33.9
	Min	32.0	35.4	32.1	34.9	32.1	34.5	32.0	34.7	32.1	34.1	31.9	33.7
20	Max	32.9	36.1	32.9	35.8	32.9	35.3	32.9	35.2	32.9	35.1	32.6	34.3
	Min	32.5	35.6	32.5	35.2	32.4	35.0	32.3	34.9	32.1	34.8	31.9	34.0
21	Max	33.0	36.3	33.1	35.8	33.1	35.7	33.2	35.8	33.1	35.4	32.9	34.9
	Min	32.4	35.9	32.8	35.1	32.7	35.2	33.1	35.1	32.8	34.9	32.1	34.5
22	Max	32.9	36.0	33.0	35.3	33.0	35.6	33.3	35.8	32.9	35.2	32.2	34.4
	Min	32.4	35.6	32.8	35.0	32.7	35.0	33.0	35.1	32.8	34.9	31.7	34.1
23	Max	32.9	36.0	32.9	35.4	32.9	35.5	33.2	35.7	33.0	35.2	32.0	34.4
	Min	32.8	35.8	32.9	55.2	32.9	35.3	33.0	35.6	32.9	35.0	31.9	34.1
24	Max	32.9	35.9	33.0	35.6	33.2	35.7	33.1	35.8	33.0	35.3	32.1	34.6
	Min	32.4	35.4	32.7	35.1	32.9	35.1	32.9	35.2	32.7	34.9	31.8	34.0
25	Max	32.8	35.8	32.9	35.2	33.3	35.6	33.0	35.5	32.4	35.1	31.3	34.1
	Min	32.4	35.6	32.7	35.0	33.0	35.1	32.8	35.1	32.2	34.9	30.2	33.8
27	Max	32.6	35.7	32.8	35.0	33.1	35.2	32.6	35.2	31.7	34.9	30.9	34.0
	Min	32.2	35.3	32.7	35.0	32.9	35.1	31.3	35.1	30.2	34.8	29.4	33.9
28	Max	32.2	35.7	32.1	35.1	32.4	35.1	28.7	35.0	28.9	34.6	28.1	33.8
	Min	31.5	35.1	30.1	34.9	30.9	34.9	27.9	34.8	26.8	34.1	26.9	33.2
29	Max	30.9	35.4	30.0	35.0	30.3	35.0	27.4	34.9	27.2	34.2	26.8	33.2
	Min	30.2	35.2	25.2	34.7	25.6	34.1	22.2	34.1	21.9	33.6	20.8	32.8
30	Max	31.3	35.2	31.8	34.2	31.9	34.3	31.8	34.1	31.8	33.4	31.3	32.8
	Min	31.0	35.0	28.9	34.0	29.1	34.0	27.9	33.9	27.9	33.2	27.3	32.3
31	Max	32.0	35.1	31.9	34.4	32.1	34.2	32.2	33.9	32.0	33.8	31.3	32.8
	Min	31.8	34.9	31.7	33.9	30.2	34.1	32.0	33.8	31.9	33.3	31.1	32.2
Monthly range		0.36	0.30	0.62	0.31	0.64	0.32	0.66	0.32	0.76	0.36	0.92	0.38

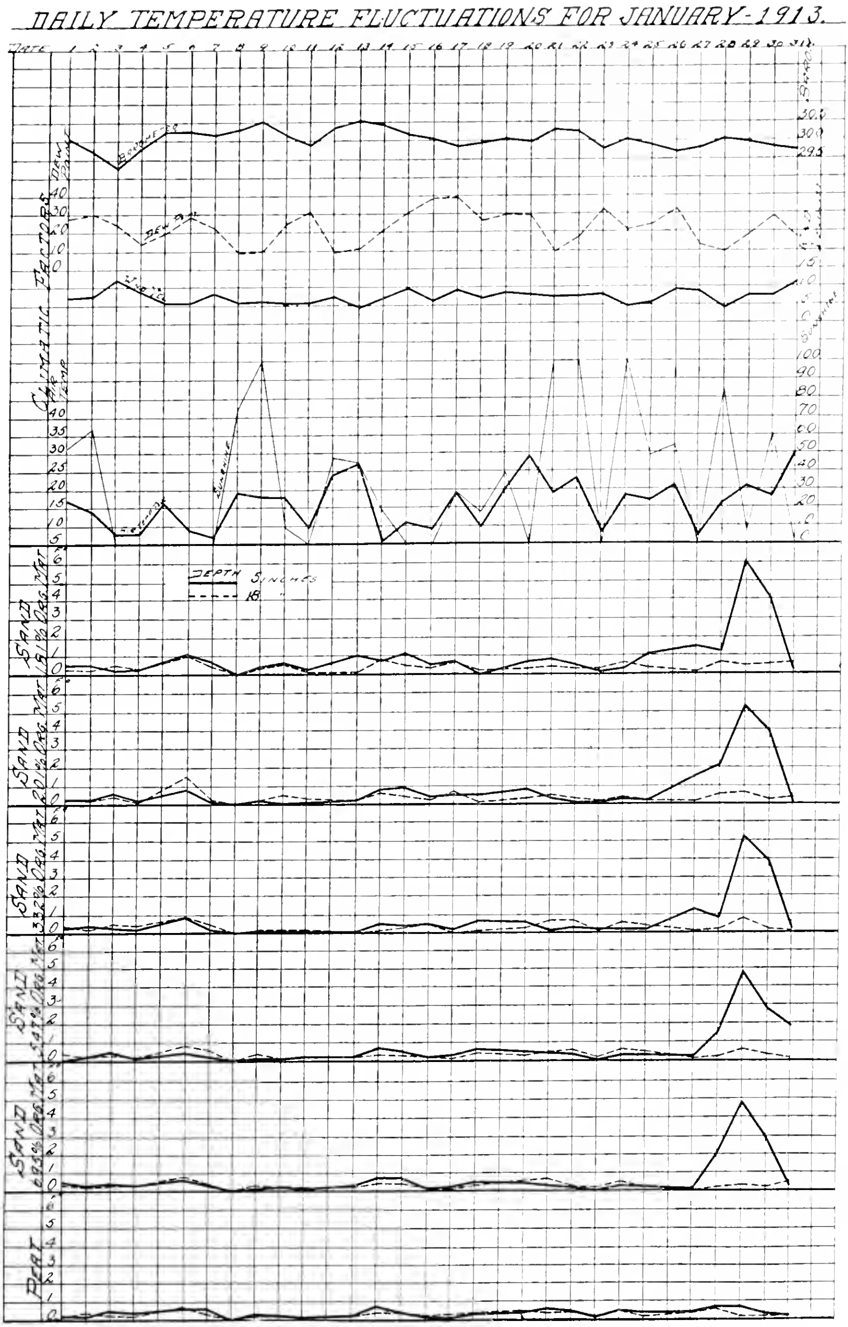
DAILY TEMPERATURE FLUCTUATIONS FOR JANUARY-1913.
DATE
CLIMATIC FACTORS
DEW POINT
BAROMETER
DEW PT.
AIR TEMP
SUNSHINE
SUNSHINE
DEPTH 3 INCHES
18 "
SAND 1.51% ORG. MAT.
SAND 20% ORG. MAT.
SAND 3.32% ORG. MAT.
SAND 5.47% ORG. MAT.
SAND 6.95% ORG. MAT.
PEAT

FIG. 50.

TABLE 69.—EFFECT OF ORGANIC MATTER ON TEMPERATURE OF SOILS. DAILY MAXIMUM AND MINIMUM, FEBRUARY, 1913.

Date	Maximum, minimum.	Peat.		6.95% Peat.		5.47% Peat.		3.32% Peat.		2.01% Peat.		1.81% Peat.	
		5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″
1	Max	28.9	35.2	26.3	34.4	26.2	34.3	25.8	34.1	26.1	33.8	25.4	33.0
	Min	28.3	35.0	23.3	31.2	23.3	34.2	21.7	34.1	23.8	33.5	23.8	32.8
3	Max	30.3	34.9	29.7	33.8	30.1	33.3	29.3	33.4	28.7	32.6	27.9	31.7
	Min	27.9	34.6	25.1	33.3	25.4	33.1	24.9	33.0	24.7	32.0	23.9	31.0
4	Max	28.7	35.0	27.0	33.8	27.0	33.6	27.0	33.4	26.2	32.4	25.1	31.1
	Min	26.3	34.9	22.0	33.4	22.3	33.5	20.9	33.1	21.1	32.2	21.0	30.7
5	Max	25.4	34.7	22.8	33.2	22.0	33.1	21.1	32.9	20.3	31.2	19.1	28.8
	Min	22.1	31.3	13.8	32.9	14.2	32.1	12.9	31.9	12.9	30.7	12.9	28.0
6	Max	25.1	34.5	24.0	33.4	22.7	32.8	20.9	31.6	20.7	30.7	19.7	27.8
	Min	20.2	34.1	13.8	32.9	13.8	31.7	13.2	30.9	12.1	29.9	12.4	26.9
7	Max	27.7	34.2	26.0	34.0	24.2	31.9	24.1	31.7	23.5	31.1	22.7	29.4
	Min	25.1	34.1	21.2	33.5	21.0	31.8	20.1	31.2	19.9	30.9	19.7	28.8
8	Max	29.0	34.2	30.1	33.2	28.2	31.3	26.8	31.3	27.2	31.2	26.7	30.1
	Min	25.5	33.3	23.1	31.8	24.0	31.1	23.8	31.1	22.8	30.8	22.2	29.6
10	Max	28.9	33.9	30.3	32.0	29.9	31.1	29.1	31.5	29.0	31.0	27.9	30.0
	Min	22.8	33.3	17.4	31.7	16.9	30.2	15.3	30.9	15.8	30.2	16.2	28.3
11	Max	29.3	33.0	29.0	31.3	29.0	31.2	29.2	31.5	29.1	31.3	27.2	30.7
	Min	29.0	32.8	28.2	31.2	27.5	31.1	25.3	31.4	26.2	30.9	25.9	30.2
12	Max	25.3	33.6	21.2	31.6	22.4	30.7	22.2	31.1	21.2	30.9	20.4	29.1
	Min	21.7	33.1	15.9	31.2	15.5	30.2	13.1	31.0	14.2	30.3	14.9	28.3
13	Max	25.7	33.2	23.2	30.7	24.9	29.2	23.8	30.0	23.3	29.8	22.4	28.0
	Min	19.2	32.9	13.1	30.0	13.2	28.3	10.3	29.4	11.8	28.9	12.1	26.8
14	Max	28.6	32.9	29.8	29.8	30.0	29.3	30.9	30.1	30.6	30.0	29.9	29.2
	Min	22.0	32.3	16.9	28.6	17.8	27.8	16.1	28.7	16.4	28.2	16.9	27.0
15	Max	29.3	32.7	30.2	30.8	30.2	30.7	30.7	31.3	30.4	31.2	29.9	30.7
	Min	29.0	31.8	29.3	29.8	28.8	29.2	29.0	29.8	27.2	28.9	26.9	26.9
17	Max	30.2	32.5	30.3	31.1	30.0	31.3	30.1	31.8	29.9	31.6	29.0	30.9
	Min	29.7	32.2	28.7	31.0	28.8	31.1	28.6	31.4	28.3	31.2	27.6	30.4
18	Max	30.0	32.4	30.8	30.9	31.0	31.0	31.9	31.6	31.2	31.3	30.4	30.8
	Min	27.3	32.2	24.8	30.3	25.2	30.7	24.7	30.9	24.0	30.9	23.7	29.2
19	Max	31.2	32.6	31.7	31.7	32.3	31.9	32.2	32.2	32.0	32.2	31.4	32.0
	Min	30.9	32.1	31.4	31.1	31.7	31.4	31.8	32.0	31.7	31.9	30.8	31.4
20	Max	31.7	32.6	32.3	31.9	32.9	32.2	34.0	32.3	33.1	32.2	32.1	32.0
	Min	31.2	32.2	31.8	31.3	32.7	31.8	33.2	31.9	32.9	31.9	31.8	31.6
21	Max	32.3	33.1	32.8	32.8	33.1	32.9	33.0	33.2	32.8	33.0	31.9	32.6
	Min	31.9	33.0	32.2	32.0	32.6	32.2	32.4	32.9	32.3	32.4	31.4	32.1
22	Max	32.1	32.8	32.3	32.2	32.7	32.4	32.4	32.9	32.4	32.7	31.7	32.2
	Min	31.8	32.6	32.0	32.0	32.3	32.2	32.1	32.7	32.0	32.3	31.2	31.8
24	Max	32.4	33.0	32.4	32.6	32.7	32.7	32.6	32.9	32.3	32.7	31.6	32.3
	Min	32.3	32.9	32.3	32.2	32.6	32.6	32.4	32.9	32.2	32.6	31.2	32.2
25	Max	31.9	32.4	32.0	32.1	32.3	32.4	32.1	32.6	31.8	32.3	30.7	31.9
	Min	31.7	32.2	31.8	31.7	31.9	31.9	31.8	32.1	31.4	32.1	30.0	31.5
26	Max	32.0	32.9	32.2	32.3	32.6	32.6	32.3	32.8	31.8	32.6	31.2	32.0
	Min	31.9	32.7	32.1	32.1	32.1	32.4	32.0	32.5	31.7	32.1	30.8	31.9
27	Max	32.1	32.7	32.3	32.3	32.3	32.4	32.2	32.8	32.0	32.4	31.2	32.0
	Min	31.8	32.2	31.9	31.9	32.1	32.1	31.9	32.3	31.8	32.0	31.0	31.7
28	Max	32.1	32.9	32.3	32.3	32.6	32.7	32.3	32.8	31.9	32.6	31.1	32.2
	Min	31.9	32.4	31.9	32.0	32.3	32.3	32.1	32.5	31.7	32.2	31.0	31.8
Monthly range		2.04	0.36	4.04	0.51	3.88	0.50	4.43	0.47	4.11	0.57	3.64	0.81

DAILY TEMPERATURE FLUCTUATIONS FOR FEBRUARY-1913

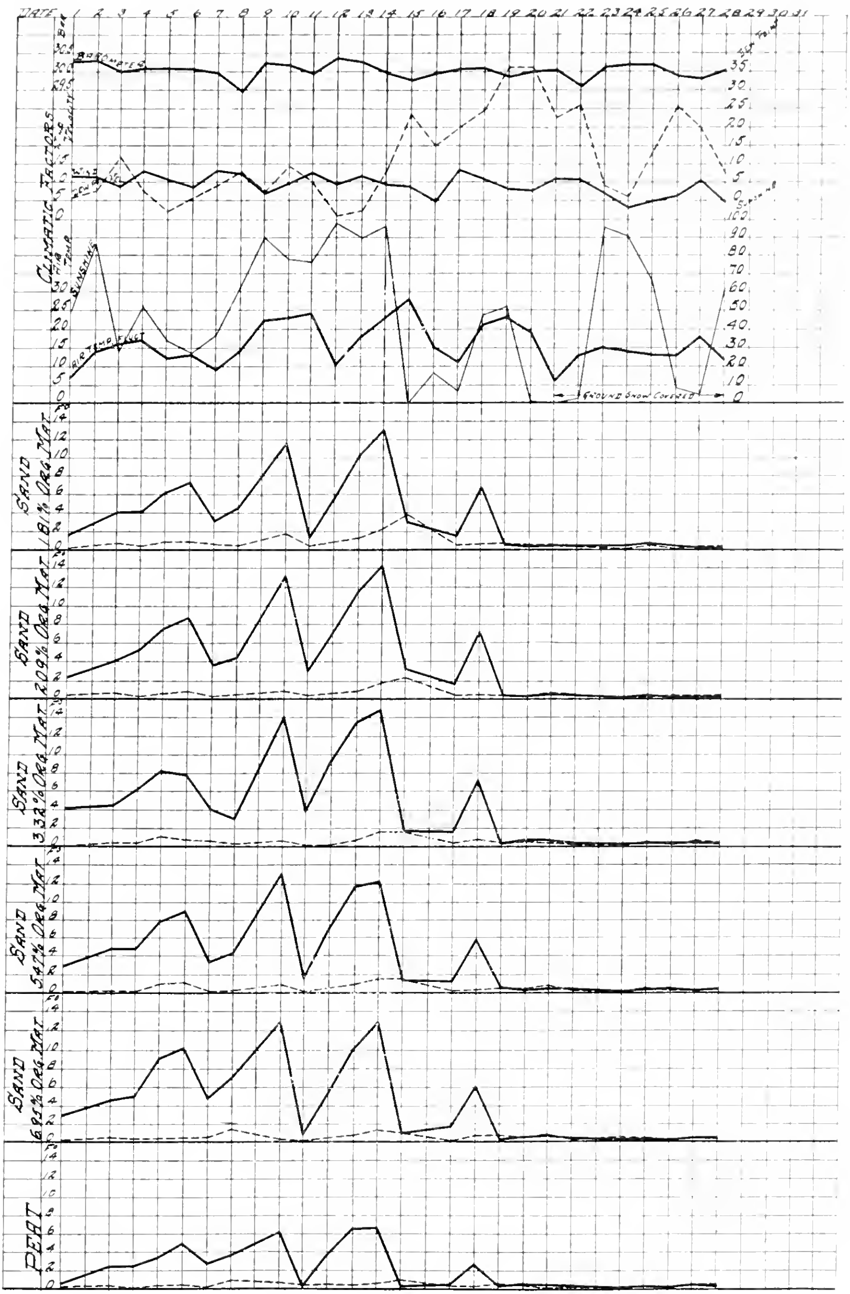

FIG. 51.

The data show that when the soils were frozen there was very little variation in temperature at both depths not only within the same soil but also among the different soils, as evidenced by the results of March when all the soils were still frozen. Immediately upon thawing and also after that until the next freezing commenced the amplitude of the upper 5 inch depth was quite marked, both within the same soil and among the different soils. In the 18 inch depth, it was comparatively small. At both depths, the soil with 3.32% organic matter gave the greatest variation in temperature followed by the soils with 2.01, 5.47, 1.81, 6.95% organic matter and lastly by pure peat. Evidently the soils with the medium amounts of organic matter gave the greatest amplitude while those with the opposite extreme of organic matter gave the smallest. This was exactly the way that their average temperature behaved.

The fluctuations of the temperature of the soils with the various amounts of organic matter did not vary greatly among themselves within the same day or month, but they varied with peat. It will be seen that the differences between the amplitudes of the former soils in the upper 5 inches varied about 2° F. the most after the month of April, but the differences between these fluctuations and those of peat were comparatively very large, ranging in the month of June for instance, 12.72° F. between the peat and the soil with 3.32% organic matter.

In the 18 inch depth the amplitudes tended to increase with the decrease in organic matter. The variations among the different soils, including the peat, ran in about the same order of magnitude as in the upper depth.

The highest daily amplitude for the 5 inch depth occurred on April 30, and the highest monthly occurred in June for both depths. June is followed in order by May, July, August, September, April, October, November, and December.

SEASONAL AND YEARLY AVERAGE AND RANGE OF TEMPERATURE.

TABLE 70.—SEASONAL AND YEARLY AVERAGE TEMPERATURES OF THE SOIL WITH DIFFERENT AMOUNT OF ORGANIC MATTER

Season.	1.81% Org. Mat.		2.09% Org. Mat.		3.32% Org. Mat		5.47% Org. Mat.		6.95% Org. Mat.		Peat.	
	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″
Spring:												
March	29.97	31.03	30.55	31.44	30.84	31.68	30.65	31.46	30.72	31.36	30.06	31.42
April	42.04	37.82	43.64	38.27	44.19	37.41	43.00	38.12	41.84	37.53	35.38	31.68
May	57.89	53.15	60.45	53.86	60.81	53.90	60.22	53.60	59.66	53.68	51.93	49.04
Ave.	**43.30**	**40.67**	**44.88**	**41.19**	**46.28**	**41.00**	**44.62**	**41.06**	**44.07**	**40.86**	**40.12**	**37.38**
Summer:												
June	67.93	63.02	70.24	63.80	70.78	64.10	70.70	63.89	70.51	64.12	64.12	62.88
July	72.85	69.58	74.55	70.03	75.23	70.11	74.85	69.77	74.93	69.99	72.81	69.41
August	68.52	66.40	70.36	67.04	70.77	67.19	70.15	66.78	70.52	66.96	68.55	66.55
Ave.	**69.77**	**66.33**	**71.72**	**66.96**	**72.26**	**67.13**	**71.90**	**66.81**	**71.99**	**67.91**	**68.49**	**66.28**
Autumn:												
September	65.69	64.93	66.96	65.57	67.15	65.68	66.96	65.50	66.61	65.53	65.80	65.81
October	49.93	51.37	50.85	52.04	50.11	52.41	50.93	52.34	50.70	52.63	50.26	53.37
November	38.72	41.60	39.58	42.80	39.68	43.34	39.92	43.46	39.97	43.63	40.45	44.67
Ave.	**51.45**	**52.63**	**52.46**	**53.47**	**52.31**	**53.81**	**52.60**	**53.77**	**52.43**	**53.93**	**52.17**	**54.62**
Winter:												
December	31.81	35.42	32.87	36.50	33.99	37.00	33.25	37.00	33.43	37.17	34.18	38.13
January—1913	30.68	33.58	31.54	34.46	31.75	34.95	32.00	34.95	31.99	35.02	32.18	35.71
February	26.19	30.50	26.88	31.52	27.10	31.93	27.53	31.73	27.48	31.99	28.66	33.23
Ave.	**29.56**	**33.17**	**30.43**	**34.16**	**30.95**	**34.63**	**30.93**	**34.56**	**30.97**	**34.73**	**31.67**	**35.69**
Yearly average	**48.52**	**48.20**	**49.87**	**48.95**	**50.45**	**49.14**	**50.01**	**49.05**	**49.87**	**49.16**	**48.11**	**48.49**

TABLE 71.—SEASONAL AND YEARLY RANGE OF TEMPERATURES OF THE SOIL WITH DIFFERENT AMOUNT OF ORGANIC MATTER.

Season.	1.81% Org. Mat.		2.08% Org. Mat.		3.32% Org. Mat.		5.47% Org. Mat.		6.95% Org. Mat.		Org. Mat.	
	5"	18"	5"	18"	5"	18"	5"	18"	5"	18"	5"	18"
Spring:												
March	0.68	0.52	0.67	0.56	0.79	0.44	0.66	0.52	0.57	0.64	0.72	0.48
April	5.23	1.60	9.85	1.39	10.33	1.55	8.29	0.93	7.03	0.69	2.57	0.28
May	11.59	2.38	13.40	1.89	13.67	1.56	12.40	1.15	11.36	0.92	3.07	0.96
Ave	**5.83**	**1.50**	**7.93**	**1.28**	**8.26**	**1.18**	**7.12**	**0.87**	**6.32**	**0.75**	**2.12**	**0.57**
Summer:												
June	13.48	2.52	14.92	2.08	15.44	1.47	14.20	1.20	13.51	0.97	2.71	0.33
July	12.57	2.29	12.63	1.90	12.63	1.51	11.40	1.25	11.25	1.10	2.96	0.64
August	10.77	2.15	12.07	1.85	12.34	1.49	11.29	1.37	10.73	1.22	2.82	0.63
Ave	**12.27**	**2.32**	**13.21**	**1.94**	**13.47**	**1.49**	**12.30**	**1.27**	**11.83**	**1.10**	**2.83**	**0.53**
Autumn:												
September	10.31	1.97	11.23	1.56	11.80	1.25	10.65	0.43	9.80	1.00	2.55	0.58
October	8.14	2.04	8.78	1.63	9.19	1.53	7.99	1.18	7.51	0.97	2.41	0.60
November	3.81	1.25	3.83	0.95	3.78	1.09	3.31	0.99	3.01	0.41	1.06	0.50
Ave	**7.42**	**1.75**	**7.95**	**1.38**	**8.26**	**1.29**	**7.32**	**0.87**	**6.77**	**0.79**	**2.01**	**0.56**
Winter:												
December	2.43	0.74	2.08	0.63	1.91	0.57	1.55	0.59	1.24	0.56	0.70	0.43
January—1913	0.92	0.38	0.76	0.36	0.66	0.32	0.64	0.32	0.62	0.31	0.36	0.30
February	3.64	0.81	4.11	0.57	4.43	0.47	3.88	0.50	4.04	0.51	2.04	0.36
Ave	**2.33**	**0.64**	**2.32**	**0.52**	**2.33**	**0.45**	**2.02**	**0.47**	**1.97**	**0.46**	**1.03**	**0.36**
Yearly range	**6.96**	**1.55**	**7.85**	**1.28**	**8.08**	**1.10**	**7.19**	**0.87**	**6.72**	**0.78**	**2.00**	**0.51**

Table 70 shows that the average temperature of all the soils was highest in summer and was followed in order by autumn, spring and lastly by winter. The temperature of all the different soils was somewhat different at the various seasons, with the greatest variation occurring in the spring and the least in the winter. In the spring and summer seasons the soil with 3.32% organic content exhibited the highest temperature at both depths, with the soils containing 2.08, 5.47, 6.95, 1.81% and peat came next in order. In the fall season, with the exception of the soil with 1.81% organic matter, the temperature was practically the same for all the other soils. For the winter season the soil with 1.81% organic matter had the lowest temperature and the peat the highest, while the temperature of the soils with 2.08, 3.32, 5.47 and 6.95% organic matter was intermediate and about the same for all of them. When the averages for the year are examined, it is found that the temperature of the soil with 1.81% organic matter and that of peat was almost the same but less than that of the soils with the intermedi-

ate percentages of organic matter; the temperature of these latter soils was also almost the same.

From table 71 it is seen that the highest seasonal amplitude occurred in summer, then in autumn, spring and winter. The greatest variation in the amplitude of the different soils was shown in the spring and the least in winter. Throughout all the seasons the soil with 3.32% organic matter exhibited the largest amplitude with the soils containing 2.01, 5.47, 6.95, and 1.81% and peat followed in order. This order maintained itself also for the year.

COMPARISON BETWEEN MONTHLY AVERAGE AND RANGE OF TEMPERATURE OF THE AIR AND THE SOILS.

TABLE 72.—COMPARISON BETWEEN THE MONTHLY AVERAGE TEMPERATURES OF THE AIR AND OF THE SOIL WITH DIFFERENT AMOUNTS OF ORGANIC MATTER.

Per cent Org. Matter	March		April		May		June		July		August	
	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″
1.81%	29.97	31.03	42.04	37.82	57.89	53.15	67.93	63.02	72.85	69.58	68.52	66.40
2.01%	30.55	31.44	43.64	38.27	60.45	53.86	70.24	63.80	74.55	70.03	70.36	67.04
3.32%	30.84	31.68	44.19	37.41	60.81	53.90	70.78	64.10	75.23	70.11	70.77	67.19
5.47%	30.65	31.46	43.09	38.12	60.22	53.60	70.70	63.89	74.85	69.77	70.15	66.78
6.95%	30.72	31.36	41.84	37.53	59.66	53.68	70.51	66.78	74.93	69.99	70.52	66.96
Peat	30.06	31.42	35.38	31.68	54.93	49.04	64.12	62.88	72.81	69.41	68.55	66.55
Air	28.38		50.22		62.00		70.78		75.77		72.34	

Per cent Org. Matter.	September		October		November		December		January, 1913.		February.	
	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″
1.81%	65.69	64.93	49.93	51.37	38.72	41.60	31.81	35.42	30.68	33.58	26.19	30.50
2.01%	66.96	65.57	50.85	52.04	39.58	42.80	32.87	36.50	31.54	34.46	26.88	31.52
3.32%	67.15	65.68	50.11	52.41	39.68	43.34	32.99	37.00	31.75	34.95	27.10	31.93
5.47%	66.96	65.50	50.93	52.37	39.92	43.46	33.25	37.00	32.00	34.95	27.53	31.73
6.95%	66.61	65.53	50.70	52.63	39.97	43.63	33.43	37.17	31.99	35.02	27.48	31.99
Peat	65.80	65.81	50.26	53.37	40.45	44.67	34.18	38.13	32.18	35.71	28.66	33.23
Air	68.90		54.55		41.71		30.58		26.44		20.63	

TABLE 73—COMPARISON BETWEEN MONTHLY RANGE OF TEMPERATURE OF THE AIR AND OF THE SOIL WITH DIFFERENT AMOUNTS OF ORGANIC MATTER.

Per cent Org. Matter	March		April		May		June		July		August	
	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″
1.81%	0.68	0.52	5.23	1.60	11.59	2.38	13.48	2.52	12.57	2.29	10.77	2.15
2.01%	0.67	0.56	9.85	1.39	13.40	1.89	14.92	2.08	12.63	1.90	12.07	1.85
3.32%	0.79	0.44	10.33	1.55	13.67	1.56	15.44	1.47	12.63	1.51	12.34	1.49
5.47%	0.66	0.52	8.29	0.93	12.40	1.15	14.20	1.20	11.40	1.25	11.29	1.37
6.95%	0.57	0.64	7.03	0.69	11.36	0.92	13.51	0.97	11.25	1.10	10.73	1.22
Peat	0.72	0.48	2.57	0.28	3.07	0.96	2.71	0.33	2.96	0.64	2.82	0.63
Air	30.49		31.12		32.48		41.06		36.98		34.18	

Per cent Org. Matter	September		October		November		December		January, 1913		February	
	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″	5″	18″
1.81%	10.31	1.97	8.14	2.04	3.81	1.25	2.43	0.74	0.92	0.38	3.64	0.81
2.01%	11.23	1.56	8.78	1.63	3.83	0.95	2.08	0.63	0.76	0.36	4.11	0.57
3.32%	11.80	1.25	9.19	1.53	3.78	1.09	1.91	0.57	0.66	0.32	4.43	0.47
5.47%	10.65	0.43	7.99	1.18	3.31	0.99	1.55	0.59	0.64	0.32	3.88	0.50
6.95%	9.80	1.00	7.51	0.97	3.01	0.41	1.24	0.56	0.62	0.31	4.04	0.51
Peat	2.55	0.58	2.41	0.60	1.06	0.50	0.50	0.43	0.36	0.30	2.04	0.36
Air	35.45		31.57		19.91		14.92		15.41		15.75	

The foregoing two tables show that the average air temperature was above the soil temperature of all depths from April to December inclusive, and below it during the months of January, February, and March. While the range of the air temperature was far greater than that of the soils and was above that of the latter throughout the year.

TEMPERATURE OF CULTIVATED, UNCULTIVATED, AND SOD LAND.

OBJECT AND METHOD OF EXPERIMENTATION.

The object of this research was to study the temperature of land under cultivated, uncultivated, and sod conditions. A few workers have already made casual observations on this line of study but no one has conducted a very thorough and extensive investigation. It was to supply the latter need that this experiment was undertaken.

The experiment was commenced in November, 1911, and the temperature of the soil under the above treatments was measured at two different depths, 7 and 20 inches respectively, by means of soil thermographs which were procured from Friez, Baltimore, Maryland. There were four thermographs, two of which were double and two single. The former were made by special order and had two soil bulbs instead of one. One of the single soil thermographs registered the air temperature also.

The ideal way to study soil temperature, in order to get the absolute maximum and minimum, would be by means of such instruments as these if they were accurate and dependable. Unfortunately, they do not always possess these qualities. On account of the large mass of liquid in the bulbs, they are slow to respond to variations of temperature; the pen is too thick, and hence, the line is too heavy for accurate readings. Again, the setting of the recording sheets around the clock is not always exactly the same for the different times. The most serious defect, however, is that the standardization is only relative, not absolute, and if a small change takes place, the experimentor may not detect it. Furthermore, the bulbs may leak and in such a case the records are worthless. This unfortunate occurrence happened twice in the present work, and hence, has broken the continuous records. The bulbs at the depth of 20 inches of the uncultivated and sod plots began to leak in January and the records of this depth of both plots were lost from this time on till May when the defective bulbs were repaired. Since the thermographs of both plots were double, the bulbs of the upper 7 inches also had to be removed in order to repair those at the lower depth, and hence, the records of the upper depths were also lost during the month of April, after the thawing had taken place. On the whole, however, these instruments gave quite satisfactory results.

In order not to disturb the natural condition of the ground the bulbs were placed in the following manner: Small trenches were dug in the ground 20 inches deep, 6 inches wide and 20 inches long. At one end of these trenches wooden rods of the same diameter as the bulbs were bored into the soil horizontally at the proper depths. The rods were then taken out, the bulbs put in their place and the trench filled up with the excavated soil. In this manner the bulbs were kept under undisturbed ground and the records, therefore, may be considered to be of soils under natural conditions right from the start.

The ground on which the plots were situated was very smooth and

slightly rolling. The soil consisted of a sandy loam. The ground had been under alfalfa sod for several years, and from the plots, which were to be left uncultivated and cultivated, the vegetation was removed long before the experiment was commenced. The plots were 20x15 feet and the bulbs were placed about 5 feet apart from each plot. The thermographs were located on top of posts 4 feet high.

The uncultivated plot was kept free from weeds, while the cultivated plot was worked always immediately after a rain. The sod plot was mowed the first of May at the time when the bulbs were placed in the soil after they were repaired. From this time on the vegetation was never cut again. Throughout the growing season, the crop grew luxuriantly and was very dense.

On account of space, the data of this experiment cannot be presented as fully and as detailed as in the preceding experiments. In the following tables, therefore, is not shown the daily temperature but only the monthly.

MONTHLY AVERAGE TEMPERATURE.

TABLE 74—AVERAGE MONTHLY TEMPERATURE OF UNCULTIVATED, CULTIVATED, AND SOD LAND.

Name of month	Uncultivated		Cultivated		Sod	
	7″	20″	7″	20″	7″	20″
December	34 5°F	36 62°F	34.84°F	35.94°F	34.38°F	37.07°F
January	27 73	....	27.79	30.92	29.22	....
February	30 73	....	29.42	30 06	30.07	....
March	31 81	....	30 60	30 67	30.81	....
April	42 24	....	39.63	37.10	41.93	....
May	....	....	54.12	50 88	....	....
June	65.25	62.00	64.4	60.64	61.97	....
July	71.09	66.94	70.04	66 61	65.55	64.0
August	66.60	63.80	66 24	63.75	63.39	63.74
September	63 48	61.90	62.80	61.84	59.60	61 40
October	50 24	50.89	50 46	50.90	48.46	52.43
November	39.77	41.20	39.50	41.27	39.85	45.07

It will be seen that in December all the plots at the depth of 7 inches had practically the same temperature. In January, the coldest month of the year, the sod plot was about 1.5 F. warmer than the other two plots, while the latter had nearly the same temperature. In the months of February and March the temperature of all the soils was almost the same with a small difference in favor of the uncultivated plot. In April the uncultivated plot had the highest temperature and was followed by the sod and finally by the cultivated. During the months of June, July, August, and September, the uncultivated plot was the warmest, the sod the coldest, while the cultivated was intermediate. The difference between the cultivated and uncultivated plots was not very great, the highest variation occurred in July (1.05° F.), followed by June (.85°), September (68°) and August (.364°). The amplitude between the sod and either of the bare plots was quite marked, ranged in July as much as about 5° F. After October the order of warmth of these plots changed somewhat. The sod which since May had the lowest temperature had now the highest, with the uncultivated and cultivated

plots next in order. The latter two soils had practically the same temperature, the difference in favor of the uncultivated plot was very slight.

The daily records, which are not shown in the above table, show that the lowest fall in temperature occurred on January 7 when the average temperature of the different soils at the 7 inch depth was as follows: cultivated 24.55°, uncultivated 22.0°, and sod 27.85°, while the highest average temperature took place on July 9 with the following results: 7 inch cultivated 76.00°, uncultivated 77.80°, sod 69.45°; 20 inch cultivated 69.0°, uncultivated 69.31°, sod 65.25°.

The first freezing occurred on December 28th. On this day the cultivated and uncultivated plots at the 7 inch depth froze at the same time, while the sod plot froze 7 days later (January 5). The first thawing took place on April 5th when both the uncultivated and the sod plots thawed at the same time. The other plot thawed about a day later.

In the second winter (1912-13) the different plots froze at the upper depth as follows: cultivated December 11th, uncultivated December 11th, sod December 13th. At the 20 inch depth the uncultivated froze Jan. 20th, cultivated Jan. 22, and sod did not freeze at all. Throughout this winter the sod plot maintained the highest temperature at both depths, the temperature of the other two plots was about he same. The results of the second winter, therefore, are in agreement with those of the first winter, the only difference being that in the second winter the effect of the vegetation in keeping the soil warm was more pronounced, due undoubtedly to the greater abundance and greater thickness of the layer of vegetation.

The foregoing data show, then, that the conditions of cultivation, non-cultivation, and sod have a very distinct influence upon soil temperature. Especially interesting is the influence of vegetation. It was observed in the first spring that the sod plot thawed at the same rate as the bare and uncultivated plot, and that its temperature rose immediately several degrees above that of the latter and remained so for the next 10 days when the plants began to grow, and then its temperature dropped back and stayed much lower than the temperature of both bare plots until September 25th. From this date on the temperature of the other two plots fell below that of the sod plot and remained so throughout the second winter and up to the middle of the second spring.

The cooling and warming effect of the cover crop in both the warmer and colder seasons of the year is self evident. In summer time the growing crop keps the soil temperature low for the following reasons: (1) Practically all the sun rays are intercepted by the growing vegetation so that the ground surface is nearly all shaded, and its temperature rise is dependent upon the wind currents and convections; (2) the air temperature around the plants and at the surface of the ground is low on account of the great amount of transpiration and evaporation that takes place. The process of evaporation has a most tremendous influence upon the diminution of temperature. The amount of transpiration by plants is not inconsiderable. Mulham makes the statement that areas covered with vegetation under the same conditions evaporate about one-third more water than a free water surface.

In the cold part of the year, the decayed and partially decayed vegetation acts as a blanket over the surface soil. This blanket performs several functions, chief of which are: First, and most important, the

prevention of the cold currents of air from coming in contact with the surface soil and thereby cooling it; second, the layer of dead vegetation, and especially when it is quite thick, is porous and the spaces are filled with air. This air being a very poor conductor of heat, does not transmit very rapidly the heat of the soil to the air above, and as a result the soil loses its heat less rapidly than if it were unprotected. Even in the summer time, the vegetation, though it is growing, acts as a blanket, and prevents the loss of heat, as evidenced by the very unappreciable variation that exists between the daily maximum and minimum temperature.

That the vegetation acts as a blanket and tends to prevent the loss of heat from the soil was confirmed also by the following experiment: A plot was covered with straw, and its fall of temperature was compared with that of a plot which remained unprotected. The results show that the uncovered soil froze at the depth of 7 inches on December 11, while that covered with straw froze on February 14th. On certain very cold nights the ground covered with straw remained as much as 10° F. warmer than the unprotected ground.

What is true of the retarding effect of vegetation on the cooling of the soil in the fall and winter applies also to its warming in the spring. If the ground has a very thick layer of dead vegetation the slow rate of warming will be evident. This does not necessarily mean, however, that the soil will have a low daily average temperature because, while the vegetation, which acts as a blanket, will prohibit a very high rise of temperature during the day it will equally prevent a very low fall of temperature during the night, and since the trend of the temperature is upward, the sod land or the land covered with straw will have a higher temperature during the early spring, especially during rapid alternation of cold and warm days, than a bare and uncultivated soil, which on account of its condition, permits greater and more nearly proportional extremes of temperature. These facts find confirmation in the present experiment. In the first spring the sod and uncultivated plots thawed on the same day and the temperature of the former plot rose several degrees higher than that of the latter, and also of the cultivated plot, within the next few days, as has already been shown. Unfortunately the thermographs were removed at this time (April) for repairs and consequently it cannot be stated how long the temperature of the sod land would have continued to be higher than that of the other plots and especially of the uncultivated plot. The uninterrupted records of the second spring, however, supply the data for this point and show that the temperature of the sod plot remained above that of the other plots until the beginning of May, when the vegetation had grown considerably. The second spring's results also show that the sod plot thawed about the same time as the other plots and that its temperature rose above that of the latter. Its average increase of temperature over the cultivated plot was 1.82° F. and over the uncultivated plot 2.34° F., for the month of April. Evidently the results of the second spring agree very well with those of the preceding spring.

The interesting question that suggests itself in connection with the temperature of soils thickly covered with crops is whether the plants themselves conduct heat into the soil, since the temperature of the latter is far below that of the air.

No positive statement can be made on either side of this question because there is no experimental data on record. Arguing theoretically, however, it would seem that the soil receives no heat or only a very unappreciable amount in this manner; first, because the plants themselves are poor conductors of heat; and second, on account of the fact that there is a tremendous amount of evaporation or transpiration going on from the surface of the plants. Since this evaporation tends to lower the surrounding temperature very markedly, the air temperature around and between the plants may not be very high or but little higher than that of the soil. Nor would it seem likely that in the cold period of the year or during the night the plants would be effective in appreciably cooling the soil by mere conduction.

The difference in temperature between the cultivated, and uncultivated plots is very interesting and needs special notice. This difference in temperature is more complex than it is commonly thought, and our present knowledge and interpretation of it are very incomplete and somewhat faulty. The common belief is that the uncultivated soil is always warmer than the cultivated during the warm part of the year. The reason given for this is that the former soil being a good conductor of heat on account of its compact condition, allows the heat to travel through it faster and to greater depths. This heat during the night recedes from the lower strata to the surface and keeps the upper layers warm, while the cultivated soil, on account of its loose state, is a poor heat propagator, and allows the heat to penetrate downward very slowly and only to a shallow depth. This soil, therefore, during the day will become very hot on the top or upper depth and during the night very cold.

The results which have been obtained in the last two years do not bear out these beliefs entirely. In the first place, the uncultivated soil is not always warmer than the cultivated during the warm part of the year, but only during certain seasons or times of this part of the year, and under certain conditions; and in the second place, the explanation given for the existing or observed difference in temperature between these two differently managed soils is neither complete, nor entirely correct.

The results obtained show that immediately after thawing in the spring the average daily temperature of the cultivated soil 7 inches deep, rose gradually above that of the uncultivated and continued to remain in excess until about the middle of May, and then the order was reversed. The average temperature of the cultivated plot for the month of April, in the spring of 1913, was 0.52° F. higher than that of the uncultivated. The records for the same month for the spring of 1912 are not so complete but those that are available tend to confirm the above general order. The uncultivated soil absorbed a greater amount of heat during the day time than the cultivated but also lost a correspondingly greater quantity of heat during the night than the latter soil. The gain and loss in heat in the uncultivated soil appears to be more nearly proportional than in the cultivated soil. The average maximum and minimum temperature for the month of April was for the uncultivated soil 47.81° and 41.80° F. and for the cultivated 47.47° and 43.17° F., respectively. The rise of temperature in the cultivated ground was starting in the morning, therefor, at a higher point, some-

times more than 3° F. higher, than in the uncultivated, so that the latter soil had to gain almost twice the amount of heat in order that its average or even its maximum temperature might equal that of the former. What brought about this gradual gain in heat in the cultivated soil will be explained subsequently. During all this time, however, that the temperature of the upper depth of the cultivated soil was higher than that of the uncultivated, the temperature of the lower depth or 20 inches of both soils was practically the same. As soon, however, as the temperature of the lower depth of the undisturbed soil began to rise higher than that of the disturbed, the temperature of the upper depth of the former also began to rise higher than that of the latter, and continued to be higher until about October. This is a strong indication that the temperature of the lower depths influences somewhat that of the upper depth, and it is probably this factor which causes the uncultivated soil, at the upper depth, to have a higher temperature than the cultivated soil, at the same depth, during the warmest part of the year.

The foregoing description of the behavior of the temperature of the cultivated and uncultivated soils, shows, therefore, that the uncultivated or compact soil is not always the warmer of the two, in the warm part of the year, as is commonly believed, but only during the warmest part of the year, and perhaps under certain conditions during the other warm seasons. The question now is what factor or factors bring about or cause this difference in temperature. The possible explanations may be found in the following general facts: When a soil is cultivated the area of its surface exposed is by far greater than that of a compacted or undisturbed soil, and of necessity the amount of evaporation in the former is greater than in the latter. As a result of this difference in evaporation the temperature of the cultivated soil does not rise, at the beginning, as high as that in the uncultivated. As soon, however, as a dry mulch is formed on the disturbed soil its loss of moisture by evaporation is reduced considerably, while the loss in the undisturbed soil is still large and consequently its rise of temperature is small. On the other hand, the heat that is not expended in the evaporation of water is rapidly conducted downward in the case of the uncultivated soil, while in the case of the cultivated soil only part of the heat is conducted downward the other part is radiated back to the atmosphere by the dry mulch at the top. This dry mulch forms a very poor and imperfect contact with the moist soil below and as a result acts as a blanket, analogous to a growing crop or a cover of straw, and does not impart all its heat to the soil below. When this mulch becomes completely dry it gets very hot during the sun insolation, in fact hotter than the air above, and a large amount of this excessive heat is radiated back to the atmosphere. This fact was proved by the following series of experiments: The bulbs of mercury thermometers were placed one inch above the surface of both the cultivated and uncultivated soils and it was found that the thermometer over the cultivated soil registered at certain days from 9 to 18° F. higher than that placed over the uncultivated soil. In another experiment the bulbs of the thermometers were placed horizontally over the surface of both soils and it was found also in this case that the surface of the cultivated soil was about 10° F. warmer than that of the uncultivated soil. In still another experiment the bulbs were simply covered with the very top surface material from both plots and the results ob-

tained were in the same order and degree of magnitude as the foregoing. All these results go to show, therefore, that a large amount of heat which is received by the surface of the cultivated soil is radiated back to the atmosphere, which accounts for its small rise of temperature during the day. The objection may be raised, however, that the greater temperature on and above the surface of the cultivated over the uncultivated soil, was probably due to the greater amount of evaporation of water in the latter. This is partly correct, and especially when the soils are very moist and the capilary action is very active, but the same results were obtained when the soils had practically the same percent of moisture.

The foregoing explanation concerning the difference in temperature between the cultivated and uncultivated soil is further confirmed by the following experiment. Wooden boxes, 12 inches square and 2 inches high, were filled with moist quartz sand. In one series the sand was well compacted and in another it was cultivated. These two series of sands were then placed outdoors during very hot days and their temperature was recorded every 15 or 30 minutes from morning till evening for two succeeding days. The results obtained are shown in the following table:

TABLE 75 — TEMPERATURE BETWEEN CULTIVATED AND UNCULTIVATED SAND—FIRST DAY.

Time	9:00 a. m.	9:15	9:30	9:45	10:00	10:15	10:30	10:45
Cultivated	53.8	55.4	56.7	57.2	59.3	61.0	62.5	64.0
Uncultivated	54.2	56.5	57.9	59.8	61.	63.	64.4	65.6
Time	11:00	11:30	12:15	12:30	12:45	1:00	1:30	2:00
Cultivated	65.8	66.8	69.8	70.6	71.2	71.8	73.0	73.5
Uncultivated	67.4	67.8	70.4	70.8	71.3	71.6	71.7	71.7
Time	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15
Cultivated	74.0	74.9	73.7	73.6	72.8	72.0	71.2	70.2
Uncultivated	71.0	71.0	70.4	69.8	68.7	67.8	66.8	65.9
Time	4:30	4:45	5:00	5:15	5:30	5:45	6:00	6:15
Cultivated	69.4	68.4	67.7	66.6	65.8	64.8	63.8	62.6
Uncultivated	65.0	64.0	63.0	62.2	61.2	60.3	59.5	58.2

SECOND DAY

Time	7:00 a. m.	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00
Cultivated.......	50.2	52.2	54.2	56.0	58.0	60.0	61.8	63.5	65.2
Uncultivated	51.4	53.8	56.2	58.3	60.7	63.1	65.2	67.4	69.6
Time	9:15	9:30	9:45	10:00	10:15	10:30	14:45	11:00	11:15
Cultivated.......	66.6	68.0	69.7	71.0	72.2	73.4	74.7	76.0	76.0
Uncultivated....	71.4	73.2	75.1	76.6	78.0	79.4	80.8	82.2	82.2
Time	11:30	12:00	12:30	1:00	1:30	2.00	7:00	7:30	8:00
Cultivated.......	77.4	78.4	80.4	81.8	82.8	83.1	52.3	52.2	52.2
Uncultivated	83.6	84.6	86.4	87.6	88.6	86.6	48.8	48.7	48.7

This table bears out the foregoing explanation perfectly. It will be seen that at the beginning of the experiment the temperature of the cultivated sand did not rise as fast as that of the uncultivated. This was due to the large amount of evaporation in the case of the cultivated sand, partly on account of its greater area exposed and partly because more heat was accumulating at the surface; and to a less amount of evaporation and to a small quantity of heat accumulating at the surface, in the case of the uncultivated sand. By 1.00 o'clock, however, the temperature of the cultivated sand attained the same degree of magnitude as the other sand. From that time on the results were reversed, the cultivated sand attained and continued to have a higher temperature than the uncultivated. This is explained on the basis that as soon as the mulch was formed on the surface of the cultivated sand the evaporation was considerably cut down, while in the uncultivated sand it was still large. The amount of heat that was expended in evaporating the moisture of the uncultivated sand was apparently larger than that radiated back to the air by the dry mulch of the cultivated sand. On the second day the results were again reversed, the cultivated sand which in the latter part of the previous day had the highest temperature of the two sands, had now the lowest. This is again explained on the basis of the moisture content and of the effect of the dry mulch. The uncultivated sand lost most of its moisture in the previous day during the time that its temperature remained below that of the cultivated, while the latter lost less except at the beginning of the experiment. The result was that the uncultivated sand was losing now a less amount of heat by evaporation and consequently utilizing more of the air temperature for the raising of its own temperature, while the cultivated sand had still some moisture below the dry mulch and on account of the slow but continuous evaporation of this moisture, and also on account of the large amount of heat received being radiated back to the atmosphere by the dry mulch, this sand, therefore, was now utilizing a less amount of heat for the raising of its own temperature, and consequently its tem-

perature was below that of the uncultivated sand. The moisture content of these series of sands was determined at the beginning and at the end of the experiment and it was found to be as follows: Initial percent moisture of both sands 8% ; at end of experiment, cultivated sand 1.4%, uncultivated sand 1.30%. The cultivated sand would show a greater moisture content if the dry mulch had been excluded from both series of sands.

The dry mulch does not only prevent the soil from attaining a high temperature during the day but also prevents the soil from attaining a low temperature during the night. Its effect here is threefold: (1) it acts as a blanket and greatly reduces the rapid loss of heat; (2) it reduces the loss of heat by cutting down the radiation, as it has already been shown; and (3) it tends to conserve moisture in the lower strata and thereby increases the specific heat of the soil and consequently reduces the rate of cooling. It is partly on account of these effects, therefore, that the cultivated soil seems to be accumulating more heat during the early spring than the uncultivated soil, and to cool less rapidly during a severe cold weather.

The effectiveness of the dry mulch to conserve moisture is shown in the following table. This table contains the percent moisture content of all the different plots as determined during the different periods.

TABLE 76.—PERCENT MOISTURE OF THE DIFFERENT PLOTS.

Date.	Uncultivated 7″	Cultivated 7″	Sod 7″
April 4	21.52	23.61	17.37
July 27	11.53	13.85	12.02
September 9	14.56	15.47	10.83
November 4	13.81	13.82	13.97

That the better heat conducting power of the uncultivated or compact soil over the cultivated or loose soil is not the greatest factor which causes the difference in temperature between these soils is further proved by the fact that the temperature begins to rise at the depth of 7 inches in the cultivated soil only about half an hour later, as has already been shown, than it does in the uncultivated soil. This is a strong evidence, that the loose soil below the dry mulch is not so poor a heat propagator as is commonly believed, and that it is not the main cause of the difference in temperature between these differently managed soils.

Summarizing the foregoing data, then, it has been seen that the uncultivated soil does not always have a higher temperature than the cultivated soil, during the warm part of the year, but only at the warmest part of this period and especially when the temperature of its lower depths is much higher than that of the corresponding depths on the cultivated soil, and that the factors which bring about the difference in temperature on these soils at the upper depths are (1) the dry mulch on the cultivated soil, (2) different rates of evaporation, (3) the different rate of heat propagation and (4) the higher temperature at the lower depths of the uncultivated over the cultivated soil.

MONTHLY RANGE OF TEMPERATURE.

TABLE 77.—MONTHLY RANGES OF TEMPERATURE OF THE UNCULTIVATED, CULTIVATED AND SOD PLOTS.

Name of month.	Uncultivated.		Cultivated.		Sod.	
	7″	20″	7″	20″	7″	20″
December	.87	.35	.49	.35	.79	.28
January	1.83	....	1.09	.18	.46	.17
February	.31	.....	.35	.38	.38	....
March	.51	....	.51	.61	.35	....
April	6.39	....	3.28	1.04	4.84	....
May	......	......	......	..	......	....
June	6.76	.8	5.40	.66	2.60	....
July	6.97	1.06	4.42	.67	1.47	.32
August	5.29	.90	3.83	.58	1.13	.52
September	5.70	1.10	4.60	1.10	1.03	.47
October	4.74	1.19	3.58	1.06	1.06	.84
November	2.40	.94	2.13	1.00	.84	.57

The foregoing table contains the monthly ranges between the maxima and minima temperature of the three different plots for the different months. It will be seen that the amplitude of the upper 7 inches of every plot increased from the winter months up to a certain time in the warm part of the year and then decreased. The maximum monthly amplitude that was reached was at different times for the various plots. For the cultivated it was in June, for the uncultivated July, and for the sod April. With the exception of the last month the variation between the highest and lowest temperature was greatest for the uncultivated, smallest for the sod and medium for the cultivated. The amplitude of the sod was very small indeed in comparison with that of the other plots.

The amplitude of the 18 inch depth is not as complete as that of the 7 inch depth but for those months that there are records for show that the magnitude was far below that of the upper depth, that it was greatest for the uncultivated, followed in order by the cultivated and finally by sod, and that the variation from month to month was not anywhere near as great, for any plot, as it was in the upper depth.

COMPARISON BETWEEN MONTHLY AVERAGE TEMPERATURE OF THE AIR AND OF THE DIFFERENT PLOTS.

TABLE 78.—COMPARISON BETWEEN MONTHLY AVERAGE TEMPERATURE OF THE AIR AND OF THE DIFFERENT PLOT.

Soils.	December.		January.		February.		March.		April.		May.	
	7″	20″	7″	20″	7″	20″	7″	20″	7″	20″	7″	20″
Uncultivated	34.50	36.62	27.73	......	30.73	......	31.81	.....	42.24		....	.....
Cultivated	34.84	35.94	27.79	30.92	29.42	30.06	30.60	30.67	39.63	37.10	54.12	50.88
Sod	34.78	37.07	29.22	....	30.07	....	30.81	....	41.93	...	.	.....
Air	31.90	....	10.80	......	17.15	.....	27.87	.....	50.57	......	61.61	......

Soils.	June.		July.		August.		September.		October.		November.	
	7″	20″	7″	20″	7″	20″	7″	20″	7″	20″	7″	20″
Uncultivated	65.25	62.00	71.09	66.94	66.60	63.80	63.48	61.90	50.24	50.89	39.77	41.20
Cultivated	64.40	60.64	70.04	66.61	66.24	63.75	62.89	61.84	50.46	50.90	39.50	41.27
Sod	61.97	....	65.55	64.00	63.39	63.74	59.60	61.40	48.46	52.43	39.85	45.07
Air	70.47	....	75.71	....	72.75	....	68.58	....	54.39	.....	41.59	....

The air temperature was above that of all the plots from April to December. The difference between the two classes of temperatures among the different plots varied in the different months.

EFFECT OF SOLUBLE SALTS ON THE RISING AND LOWERING OF TEMPERATURE OF SOILS.

OBJECT AND METHOD OF EXPERIMENTATION.

Solutions possess many physical properties which have a very decided influence on temperature. Solutions of greater densities possess a lower freezing point, a higher boiling point, a lower vapor pressure, a higher surface tension and a higher viscosity, than solutions of lower concentration. All these properties vary with the composition of the solution and influence the rising and lowering of temperature either directly or indirectly. Soils, therefore, with different densities of solution will have different rising and lowering of temperature. Rising and lowering are employed here as general terms and are intended to include the rate of freezing, the degree of the lowering of the freezing point, the rate of thawing, the rate and degree of rising temperature, etc.

In the literature of soil temperature no record is found on the effect of soluble salts on the rising of soil temperature, but there is one work reported on the other phase of this subject. This is by Ulrich.[18] and it is on the influence of frosts on the temperature conditions of soils with different salt content. He conducted the investigation by mixing fine kaolin in cylinders with .05, 0.1 and 0.2 percent of $Co(OH)_2$, $NaCl_2$, $NaNo_3$, and some other salts and subjected the mixtures to temperatures varying from 0 to −10° C. The results show, in general, that the temperature of freezing was lowered by the addition of salts, the greater the amount of salt present the greater the lowering of temperature. When the soil water froze the temperature of the soil rose at once to 0° C., remained for a time at this point and then gradually fell under the influence of the low temperature. Certain salts, such as $Ca(OH)_2$, $CdCl_2$, etc., retarded this fall of temperature, others such as KOH, etc., hastened it.

In order to ascertain more positively, if possible, to what extent the cooling and warming of the soil is affected by the different soluble salts and what kind of salts have the greatest influence in either respect, the folowing experiments were undertaken. They consisted in placing equal amounts of quartz sand in wooden boxes, 12 inches square and 2 inches high with bottoms and no top, and then placing this sand in the boxes out doors on a stand to study either the lowering or rising of temperature. The quartz sand in the different boxes was previously thoroughly moistened with different solutions of various concentrations. These densities varied from one-half to three times normal. Where direct comparison was desired, either between the different concentrations within the same salt or between different salts, the same amounts of solution were added to equal weights of quartz sand. The study of the rising of temperature was conducted during clear hot days in summer, and that of the lowering of temperature was carried on during

[18] Forsch. a. d. G. a. Agrik. Phy. II : 218 – 229, 1897.

cold evenings in the winter. In the former case, the temperatures were read on Centigrade thermometers reading from 0 to 110° and graduated to 0.1°, while in the latter case Fahrenheit thermometers were employed, especially constructed for the purpose which read from -32 to +100° and were graduated to 0.2°.

The data obtained for both studies are contained in the following pages. The results of the rising of temperature will be presented first.

RISING OF TEMPERATURE.

Experiment 1. This was a preliminary experiment. It consisted of studying the effect of KCL on the rise of temperature in comparison with that of water. The solution was prepared by dissolving three times the molecular weight of the salt in one liter of water. Then 250 cc. of the solution as well as of water were added to portions of 6372 grams of quartz sand. The duplicate boxes containing the moist sand were then placed in the sun and the temperature records were taken at various times. The results obtained are given herewith:

TABLE 79.—EFFECT OF SALT SOLUTIONS ON THE RISE OF SOIL TEMPERATURE.

Name of solution.	9:30 a. m.	11:00 a. m.	1:00 p. m.	4:00 p. m.	9:00 p. m.
H_2O....	21.00°C	24.43°C	28.68°C	23.49°C	17.43°C
KCl.......	21.55	27.04	30.88	24.08	17.70

It will be seen that at the beginning the temperature of both H_2O and KCL treated sand is practically the same, but that from then on the temperature of the KCL rises more rapidly than that of the water and at 1:00 P. M. when the maximum of both was reached, the difference is 2.20° C. in favor of the KCL treated sand. From that period on the temperature of both series falls and at 9:00 P. M. it is again about the same.

Experiment 2. In this experiment NH_4Cl, $NaNo_3$ and $CaCl_2$ were used. Their solutions were prepared by dissolving three times their normal molecular weight in one liter of water. Exactly 450 cc. of each solution was added to 5,770 grams of sand; the same number of cubic centimeters of water being also added to an equal weight of sand for comparison or as a standard. The moistened sand was then placed in the regular boxes and the temperature rise was studied on a warm clear day. The following are the results of this experiment:

TABLE 80.—EFFECT OF SOLUBLE SALTS ON THE RISE OF SOIL TEMPERATURE.

Name of solution.	9:00 a. m.	11:30 a. m.	1:30 p. m.	5:30 p. m.
H_2O..........	20.85°C	24.03°C	22.90°C	18.93°C
NH_4Cl..........	21.90	26.86	26.93	20.70
$CaCl_2$..........	22.23	27.72	27.45	20.20
$NaNo_3$..........	22.00	26.78	26.50	20.73

As in the foregoing experiment these figures show that at 1:30 P. M. when the maximum temperature was reached, the sand treated with the different salts was much warmer than that treated with water. The highest temperature attained was by $CaCl_2$ and followed respectively by NH_4Cl, $NaNo_3$ and water. The amplitude between the $CaCl_2$ and water is 4.55°.

Experiment 3. In this experiment K_2HPO_4, K_2CO_3 and K_2SO_4 were employed and as usual their solutions were prepared by dissolving three times their equivalent molecular weight in one liter of water, then 460 cc. of each solution as well as of water were added to 6500 grams of sand. The temperature records were made in the manner already described and the following data were obtained:

TABLE 81.—EFFECT OF SOLUBLE SALTS ON THE RISE OF SOIL TEMPERATURE.

Name of solution.	8:45 a. m.	11:25 a. m.	1:30 p. m.	6:30 p. m.
H_2O	23.40°C	25.10°C	27.20°C	20.30°C
K_2HPO_4	23.15	27.53	31.20	21.40
K_2CO_3	23.13	32.03	35.25	22.93
K_2SO_4	23.55	29.48	32.38	21.83

This experiment gives more confirming evidence that the density of solution brings about a rising of temperature in soils. It is seen that at 1:30 P. M. the difference in temperature between pure water and K_2CO_3 is 8.05° in favor of the latter.

The difference observed in temperature between the last different salt solutions is partly due to unequal concentration because of different solubility of the salts. Only about half of the K_2SO_4 and about three-fourths of the K_2HPO_4 dissolved, while the whole amount of the K_2CO_3 went into solution.

Experiment 4. In the foregoing experiments different salts of the same density were used. In this experiment different densities of the same salt solution were tested. The salt used was NaCl in the proportion of 0.0, 1, 2, and 3 times its normal molecular weight in one liter of water. Exactly 460 cc. of each solution were added to 6500 grams of sand. The temperature data obtained are given below:

TABLE 82.—EFFECT OF DIFFERENT DENSITIES OF SOLUTION ON THE RISE OF SOIL TEMPERATURE.

Name of solution.	9:00 a. m.	11:15 a. m.	1:00 p. m.	2:30 p. m.
H_2O	19.73°C	23.4 °C	24.95°C	24.75°C
1 N NaCl	19.13	25.8	27.63	27.13
2 N NaCl	19.00	26.35	29.25	28.6
3 N NaCl	18.75	26.53	30.48	29.85

It is seen that at the different periods and especially at 1:00 P. M. when the maximum temperature was attained, the temperature rise increases with the increase in density. At this latter period the differ-

ence between the pure water and the highest concentration is 5.53°.

Experiment 5. In this experiment an attempt was made to study the influence of the salt solutions on the rise of temperature under practical conditions. The experiment was performed by inserting into the ground mercury thermometers to a depth of three inches, and 12 inches apart, and placing over an equal area, around each thermometer, equal quantities of water and some kind of salt solution. The general trend of the different tests is well illustrated by the experiment below in which NaCl and H_2O were used. Exactly 500 cc. of each was poured around each thermometer. The solution was prepared by dissolving 100 grams of the salt in one liter of water.

TABLE 83.—EFFECT OF SOLUBLE SALTS ON THE RISE OF SOIL TEMPERATURE.

Name of solution.	10:00 a. m.	1:50 p m.	3:10 p. m.	5:45 p. m.
H_2O	68.5°F	75.5°F	76.7°F	76.0°F
NaCl	68.5	81.5	83.4	80.8

It is evident that as in the preceding experiments with sand, the salt solution has a predominate influence on the rise of temperature. It will be seen that at 3:10 when the maximum temperature was attained for the day the soil treated with the salt solution is 6.70° F. warmer than the soil treated with pure water.

That the concentration of solution influences the rising of temperature and that this degree of rising may be considerable is beyond any doubt from the foregoing work. The question now is what factor or factors bring about this result. From all evidence it appears to be due to the diminution of evaporation of water by the higher surface tension and lower vapor tension of the higher densities. If this be so then the sand treated with the most concentrated solutions should contain at the end of a certain period or at the time when the maximum temperature is attained, a higher percentage of moisture than the sand to which was added pure water or dilute solutions. The determination of the moisture content of some of the lots of sand shows such to be the case. These moisture tests were made by pouring all the sand contained in the box into a large pan thoroughly mixing it and taking composite sample from the mass. The results obtained are given herewith:

TABLE 84.—MOISTURE CONTENT AT END OF EXPERIMENT.

Name of solution.	Per cent moisture.
H_2O	2.30
KH_2PO_4	3.25
K_2CO_3	4.7
K_2SO_4	4.0

It will be seen that the moisture content is higher in the sand treated with the salt than with pure water, hence it supports the hypothesis.

The interesting question that arises now is: Is the influence of the density of the salt solutions permanent or temporary? In other words, will the temperature of the sand or soil treated with the salt solutions always continue to be higher than that of the sand or soils treated with water? For the answer of this question the experiment below was conducted. It consisted in treating sand with normal solutions of KH_2PO_4, KCL, and $NaNO_3$, and studying the temperature for a number of days. The data obtained are presented in the following table:

TABLE 85.—EFFECT OF SOLUBLE SALTS ON THE RISE OF SOIL TEMPERATURE.

Name of solution.	First day.		Second day.		Third day.		Fourth day.	
	8:45 a. m.	12 m.	7:00 a. m.	1:15 p. m.	8:00 a. m.	1:30 p. m.	8:00 a. m.	2:00 p. m.
H_2O	24.15°C	27.9 °C	17.2 °C	29.35°C	22.8 °C	39.95°C	22.0 °C	39.4°C
KH_2PO_4	24.0	29.5	17.5	30.15	22.25	37.60	22.10	37.5
KCl	23.85	30.7	17.6	31.35	22.65	39.75	22.45	38.2
$NaNO_3$	23.80	31.55	17.65	32.25	22.8	38.7	22.7	37.7

These results show that on the first day the temperature of the sand treated with the salt solution is considerably higher than that of the sand treated with pure water but the differences decrease in each succeeding day until the third day they not only disappear but the previous order is reversed: the sand treated with water has a higher temperature than the sand treated with the salt solutions.

The same order of results were also obtained with the soil: after the first day the temperature of both series was about the same.

This reversed order of the results may be explained again on the basis of the moisture content. The percentage of moisture of the sand differently treated was determined at the end of the third day with the following results:

TABLE 86.—MOISTURE CONTENT AT END OF EXPERIMENT.

Name of solution.	Per cent moisture.
H_2O	.82
KH_2PO_4	1.16
KCl	1.67
$NaNO_3$	1.90

It is seen that even now the moisture content of the sand treated with the salt solutions is much higher than that of the sand treated with pure water, but in both cases the amounts are quite low. Now it is conceived that in the sand treated with water, there is very little evaporation going on because the moisture present is reduced almost to the hygroscopic state, while in the sand treated with the salt solutions there is some evaporation going on because the moisture content is still con-

siderable. The result is that the temperature of the former is raised above that of the latter.

In humid regions the effect of density of the soil solution upon the diminution of evaporation and hence upon the rising of temperature, is probably not very large but in the air dry regions in the alkaline lands —it must be very considerable.

The interesting question that arises now is, is the temperature of the leaves of plants grown in different densities of solution any different. The writer[19] has shown that the density of the plant cell sap increased with the increase in concentration of the solution in which the plants grew and that the relative transpiration or the number of grams of water transpired to produce one gram of dry matter decreased, above a certain point, with the increase in concentration of the solution. In the light of all these facts the conclusion is irresistable that the leaves of plants grown in solutions of high concentration must have a higher temperature during the summer than the leaves of plants grown in solution of low concentration. In the winter however, the former leaves will have a lower freezing point than the latter leaves.

LOWERING OF TEMPERATURE.

The effect of salt solutions upon the cooling or lowering of temperature of soils was studied in the same manner as the foregoing with few exceptions. The chief differences being that the present study was conducted in winter when the air temperature was very low, the thermometers used were differently constructed, and that in some cases earthenware jars 3 inches high and 3 inches in diameter were used instead of the wooden boxes. The extent and nature of the work will be revealed in the description and discussion of the following experiments:

Experiment 1. This experiment consisted in studying the effect of different concentrations of KCl and NH_4Cl upon the rate of cooling and the degree of lowering of the freezing point and also upon the rate of thawing and rising of temperature. The experiment was prepared by placing 1546 grams of quartz sand in the earthenware jars and adding to the sand 300 cc of solutions of 0.0, 0.5, 1.0 and 1.5 normal of KCl and NH_4Cl; then placing the vessels containing the sand outdoors upon a stand during a cold night and taking records of the rate of falling of temperature every 10 minutes with thermometers graduated to 0.2° F., until the temperature of the sand in all the pots was about the same as the air temperature. The next morning when the air temperature began to rise, the jars were brought into the laboratory, whose temperature remained quite constant along 65° F., and the rate of thawing and rising of temperature was studied by taking records every 10 minutes until the sand in all the different pots was about the same and close to the room temperature. The data obtained in this experiment are shown in the tables below with their accompanied charts:

[19] Bouyoucos, G. J. Transpiration of wheat seedlings as affected by different densities of a complete nutrient solution in water, sand and soil cultures.
Beihefte zum Botanischen Centralblatt.
Heft 1, November, 1912.

TABLE 87. EFFECT OF SALT SOLUTIONS ON THE RATE OF FREEZING AND THE DEGREE OF THE LOWERING OF THE FREEZING POINT.

Time.	P. M. 3:55	4:05	4:15	4:25	4:35	4:45	4:55	5:05	5.15	5:25	5:35	5:45	5:55
H_2O	61.9	54.2	49.7	44.8	41.0	36.6	31.0	32.1	32.0	31.8	31.8	31.8	31.8
0.5n KCl	61.7	54.0	49.8	44.9	41.1	36.9	33.3	30.0	28.6	28.8	28.8	28.8	28.8
1.0n KCl	61.4	53.8	49.4	44.7	40.9	36.5	33.0	29.6	26.8	25.2	23.4	25.6	25.6
1.5n KCl	61.8	54.2	49.7	44.8	41.0	36.6	33.0	29.6	26.8	25.0	23.2	21.6	29.4
0.5n NH_4Cl	62.5	54.2	49.7	44.9	41.0	36.7	33.0	29.8	28.0	28.4	28.4	28.4	28.4
1.0n NH_4Cl	62.0	54.6	50.3	45.6	41.7	37.7	33.6	30.6	27.8	26.0	24.4	25.0	25.0
1.5n NH_4Cl	62.2	54.8	50.4	45.6	41.7	37.5	33.5	30.2	27.4	25.6	24.0	22.6	22.0
Air	20.5	19.5	19.0	18.0	16.5	13.5	13.5	13.0	13.0	12.5	12.5	12.0	12.0

Time.	P. M. 6:05	6:15	6:25	6:35	6:45	6:55	7:05	7:15	7:25	7:35	7:45	7:55
H_2O	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.6	31.4	30.9	30.0
0.5n KCl	28.6	28.6	28.4	28.2	27.8	27.5	27.2	26.8	26.4	25.8	25.4	25.0
1.0n KCl	25.6	25.4	25.2	25.0	24.5	24.1	23.6	23.4	23.0	22.6	22.1	22.0
1.5n KCl	19.2	20.6	20.8	20.8	20.6	20.4	20.1	19.9	19.6	19.4	19.2	19.0
0.5n NH_4Cl	28.2	28.2	28.2	28.2	27.6	27.6	27.1	26.6	25.8	25.0	24.4	23.6
0.0n NH_4Cl	25.0	25.0	25.0	25.0	24.8	24.4	24.1	24.0	23.6	23.4	23.0	22.8
1.5n NH_4Cl	22.0	22.0	22.0	22.0	21.8	21.6	21.4	21.2	21.0	20.6	20.4	20.2
Air	11.7	11.5	11.5	11.5	11.3	11.3	11.3	11.2	12.0	12.2	12.5	12.2

Time.	P. M. 8:05	8:15	8:25	8.35	8:45	8.55	9:05	9:15	9:25	9:35	9:45	9:55
H_2O	29.2	28.1	26.8	25.0	23.6	22.4	21.8	21.4	20.7	20.0	19.4	18.9
0.5n KCl	24.6	24.4	24.0	23.6	23.2	23.0	22.6	22.2	21.9	21.6	21.2	20.8
1.0n KCl	21.8	21.5	21.2	21.0	20.8	20.6	20.4	20.2	20.0	19.8	19.6	19.4
1.5n KCl	18.8	18.7	18.6	18.4	18.4	18.2	18.2	18.1	18.0	17.9	17.8	17.7
0.5n NH_4Cl	23.2	22.6	22.2	21.6	21.2	20.7	20.2	19.8	19.4	19.0	18.6	18.4
1.0n NH_4Cl	22.6	22.4	22.2	22.0	21.8	21.6	21.4	21.2	21.0	21.0	20.8	20.5
1.5n NH_4Cl	20.0	19.8	19.8	19.6	19.4	19.4	19.2	19.0	19.0	18.8	18.7	18.6
Air	13.5	12.4	13.0	12.5	12.0	13.0	14.0	14.0	13.0	12.5	14.0	14.0

Time.	P. M. 10:05	10:15	10:25	10:35	10:45	10.55	11:05	11.15	11.25	11:35	11:45	11:55
H_2O	18.5	18.2	17.7	17.3	16.8	16.4	16.2	15.9	15.8	15.6	15.6	15.6
0.5n KCl	20.6	20.2	19.9	19.6	19.2	18.9	18.4	18.2	18.0	17.8	17.6	17.4
1.0n KCl	19.2	19.0	18.9	18.8	18.5	18.3	18.0	17.8	17.6	17.5	17.4	17.3
1.5n KCl	17.6	17.6	17.5	17.4	17.3	17.2	17.0	16.9	16.8	16.8	16.7	16.6
0.5n NH_4Cl	18.2	17.8	17.6	17.3	17.0	16.8	16.4	16.2	16.2	16.0	15.9	15.8
1.0n NH_4Cl	20.4	20.2	20.0	19.8	19.6	19.4	19.2	19.0	18.8	18.6	18.5	18.4
1.5n NH_4Cl	18.5	18.4	18.3	18.2	18.0	17.9	17.8	17.6	17.6	17.4	17.4	17.2
Air	14.3	13.5	14.2	13.0	13.0	13.0	13.8	14.0	13.8	14.0	14.2	14.0

TABLE 88.—EFFECT OF SALT SOLUTIONS ON THE RATE OF THAWING AND THE DEGREE OF THE RISING OF TEMPERATURE.

Time.	A. M. 8:00	8.10	8.20	8.30	8.40	8.50	9:00	9.10	9:20	9.30	9.40
H_2O	1.2	10.0	15.0	20.3	24.4	27.0	29.8	30.6	31.2	31.3	31.4
0.5n.KCl	2.9	9.6	11.2	11.8	13.8	17.0	19.6	21.2	22.7	23.6	24.6
1.0n.KCl	3.4	10.0	11.2	11.8	12.0	12.4	12.6	15.0	17.8	19.0	20.4
1.5n.KCl	3.4	5.6	11.2	11.6	11.8	11.9	12.0	12.1	12.4	12.8	14.8
0.5n.NH_4Cl	2.8	8.6	12.1	15.8	18.6	20.4	22.0	23.2	24.3	25.0	25.7
1.0n.NH_4Cl	3.3	5.6	8.9	12.1	14.6	16.3	18.0	19.2	20.4	21.2	22.0
1.5n.NH_4Cl	3.2	4.2	6.1	9.5	11.2	14.0	15.8	17.0	17.4	19.2	20.3
Air	63.	63.0	63.5	63.5	64.0	64.0	64.5	64.5	65.0	65.0	65.3

Time.	A. M. 9:50	10.00	10:10	10:20	10:30	10:40	10.50	11:00	11:10	11:20	11:30
H_2O	31.5	31.6	31.6	31.7	31.7	31.8	31.8	31.8	31.8	31.8	31.8
0.5n.KCl	25.2	25.7	26.3	26.6	26.9	27.2	27.5	27.8	28.1	28.4	29.0
1.0n.KCl	21.3	22.0	22.6	23.0	23.8	24.3	25.0	26.0	27.2	31.4	34.2
1.5n KCl	17.0	18.2	19.3	21.1	23.4	25.2	28.9	32.2	34.8	37.2	39.4
0.5n.NH_4Cl	26.2	26.6	26.9	27.2	27.5	27.8	28.1	28.5	29.5	31.3	33.6
1.0n.NH_4Cl	22.6	23.2	23.7	24.0	24.6	25.0	25.7	27.2	29.2	32.4	34.6
1.5n.NH_4Cl	21.0	21.8	23.0	25.2	28.5	31.4	34.8	36.3	38.3	40.5	42.2
Air	66.5	66.5	66.8	67.0	67.5	68.5	68.5	68.5	68.5	69.0	69.0

Time.	A. M. 11:40	11:50	M. 12:00	P. M. 12:10	12:20	12:30	12:40	12:50	1:00	1:10	1:20
H_2O	31.8	32.0	32.1	32.1	32.2	33.0	34.6	37.2	40.5	43.6	46.1
0.5n.KCl	30.0	33.4	36.1	38.5	40.5	42.2	44.0	45.6	47.2	48.7	50.3
1.0n.KCl	35.8	38.7	40.5	42.7	44.1	45.5	47.0	48.2	49.6	50.9	52.3
1.5n.KCl	40.8	43.2	44.7	46.1	47.4	48.5	49.6	50.6	51.7	52.8	53.8
0.5n.NH_4Cl	33.8	40.9	43.0	44.2	46.4	47.8	49.2	50.4	51.6	52.8	54.1
1.0n.NH_4Cl	36.4	39.4	41.0	42.8	44.4	45.7	47.4	48.4	50.5	51.0	52.2
1.5n.NH_4Cl	43.4	45.4	46.6	47.9	49.0	49.8	50.8	51.6	52.6	53.6	54.6
Air	69.0	67.8	67.0	68.0	68.5	67.5	69.5	69.5	70.0	69.0	69.0

Time.	P. M. 1:30	1:40	1:50	2:00	2:10	2:20	2:30	2:40	2:50	3:00
H_2O	47.4	49.2	50.8	52.2	53.8	54.5	55.4	56.3	57.3	58.0
0.5n.KCl	51.1	52.3	53.5	54.4	55.2	55.9	56.6	57.3	57.8	58.5
1.0n.KCl	53.0	54.0	55.0	55.8	56.5	57.0	57.8	58.3	58.9	59.4
1.5n.KCl	54.4	55.2	56.0	56.6	57.5	57.8	58.4	58.8	59.3	59.8
0.5n.NH_4Cl	54.7	55.7	56.6	57.3	58.0	58.5	59.1	59.6	60.1	60.6
1.0n.NH_4Cl	52.9	54.0	55.0	55.6	56.2	57.0	57.6	58.2	58.7	59.2
1.5n.NH_4Cl	55.0	55.6	56.5	57.2	57.8	58.2	58.8	59.2	59.6	60.1
Air	69.0	68.5	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0


TEMPERATURE
TIME
KCL-RATE OF RISING OF TEMPERATURE
KCL RATE OF LOWERING OF TEMPERATURE
AIR TEMP
AIR TEMP
.02N
.01N
.10N
.15N
.01N
.02N
.10N
.15N

FIG. 52.

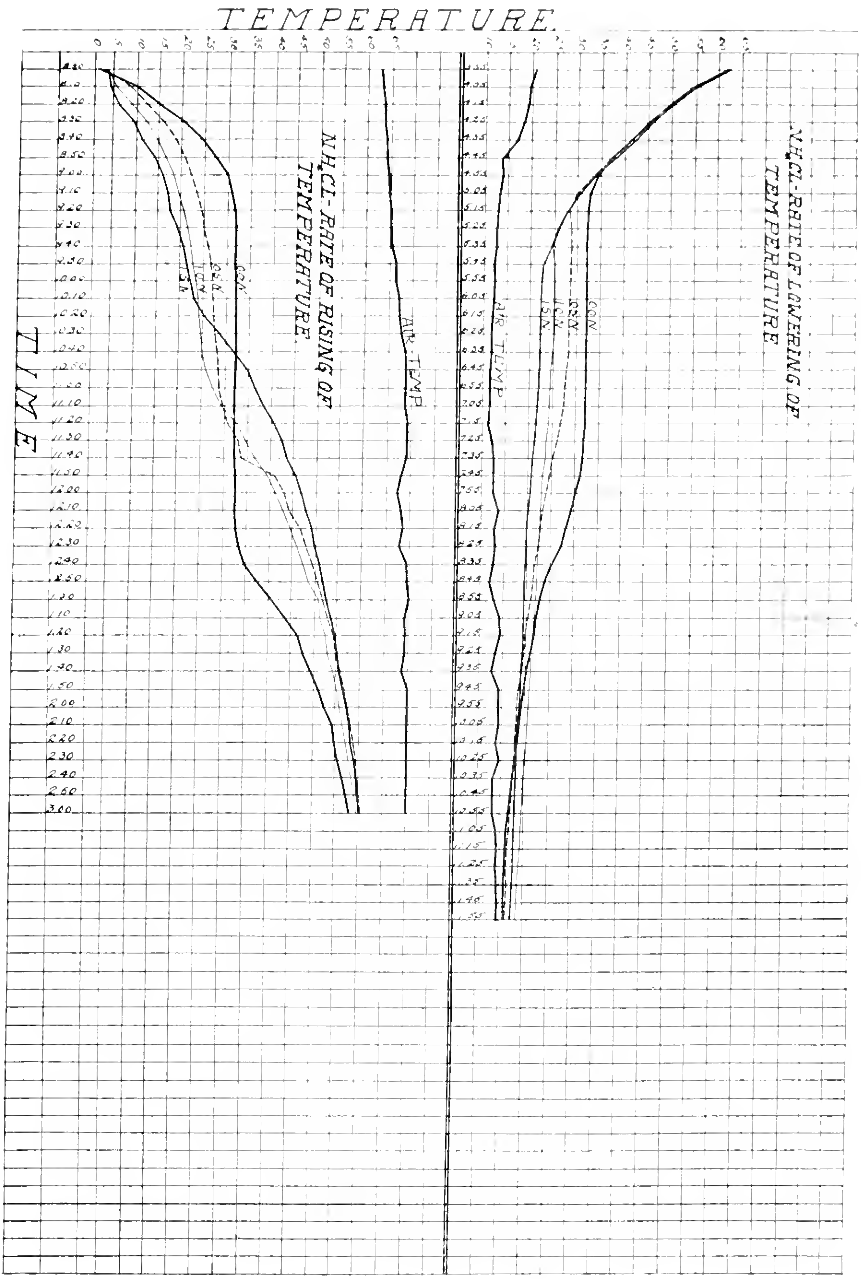
TEMPERATURE.
TIME
NH4CL-RATE OF RISING OF TEMPERATURE.
NH4CL-RATE OF LOWERING OF TEMPERATURE
AIR TEMP.
AIR TEMP.
60N
25N
10N
15N
60N
25N
10N
5N

FIG. 53.

The foregoing tables and charts show many extremely interesting facts. Considering first the rate of freezing it will be seen that the sand treated with the different solutions and with pure water cooled at about the same rate until the temperature of about 34° F. was reached when the rate of falling of temperature of the sand treated with the water slowed up while the temperature of the sand treated with the solutions continued to fall until the respective freezing points were reached. The sand, therefore, treated with the solutions came to the temperature of 32° F. about 15 minutes before did the sand treated with water. The freezing point of the sand with the different treatments is markedly different; that with water is 31.8°., that with 0.5, 1.0 and 1.5 normal solutions of KCl is 28.8°, 25.6° and 20.8° respectively, while that with 0.5 1.0 and 1.5 normal solutions of NH_4Cl is 28.4, 25, and 22° respectively. From these figures it is evident that the salts have lowered the freezing point and the degree of this lowering is greater with the higher salt content present. After the temperature of all the different treatments reached the freezing it remained there for some length of time, which amount of time varied with the concentration: it was greatest for the pure water and decreased with the increase in concentration of the solution. This is an interesting fact and it is explained by the difference in the further lowering of the freezing point due to the further increase in concentration of the solution brought about by the separation of the solidified solvent or ice under the subjection of the low temperature. Finally, however, the temperature of the sand which received the different densities of solution as well as the water, came to about the same point, with a slight difference in favor of the solution treated with sand. It is to be noted that the phenomenon of supercooling, such as observed in the freezing of water in the form of drops or in capillary tubes, also occurred in the freezing of soil water. It will be seen that in almost every case some supercooling did take place.

It will be interesting now to study the rate of thawing and rising of temperature of the same lot of sands and see what relationship it has to the rate of freezing. As already stated, this rate of thawing and rising of temperature was measured by bringing the sands into the laboratory after their temperature was lowered to about the same point, and records were taken every 10 minutes until their temperature was about the same and close to the room temperature. The data thus obtained are shown in table 88, and on the lower part of each chart. A glance at these results reveals at once the significant fact that the rate of thawing was in every case, exactly the reverse of the rate of freezing. It will be seen that the temperature of the sand treated with the water rose at once to 31.8° F. or at the point in which solidification took place and remained there for a long time until all the solid phase had been converted over into the liquid phase and then it rose very rapidly. While the temperature of the sand treated with the solutions rose at the beginning slowly and gradually without remaining at any one point for any length of time—which is just what should be expected since fusion and solidification take place at the same point and since there were more than one freezing point in the case of these solutions on account of their further concentration due to the separation of ice—until complete fusion had taken place and then it rose very rapidly and far above that of the sand treated with water. The rapidity with

which complete fusion took place and the temperature passed the 32° F. point was proportional to the concentration of the treatment. It will be noticed that by the time the temperature of the sand treated with water began to rise above 32° F., the degree of magnitude of the temperature of the other lots of sand varied directly with the density of the solution. In the case of the KCl experiment for instance, the difference in temperature between the sand treated with water and that treated with 1.5 normal solution was as great as 17° F. Finally, however, all the differently treated sands attained about the same temperature. The differences noted increase with the decrease in concentration of the solution and would necessarily exist on account of the difference in evaporation.

Experiment 2. This experiment was an extension and check to the foregoing experiment. It consisted in studying the effect of 0.0, 0.5, 1.0 and 1.5 normal solutions of NaCl and KCl and 1.0 normal solutions of K_2CO_3, $NaNO_3$, $CaCl_2$ KNO_3, and $(NH_4)_2CO_3$ upon the rate of freezing, the degree of the lowering of the freezing point, and the rate of the rising of temperature. It was prepared by placing 6855 grams of quartz sand in the regular wooden boxes, added 750 cc of the respective solutions, and the temperature records were taken in the usual manner. In the table below is given only the lowering of the freezing point, the rate of freezing and of thawing are left out on account of lack of space; the general trend of these, however, is well illustrated in the foregoing experiment.

TABLE 89.—FREEZING POINT OF SOLUTIONS IN SAND.

Name of solution.	Freezing point.
Water	31.8
0.5 N. NaCl	28.8
1.0 N. NaCl	25.4
1.5 N. NaCl	22.2
0.5 N. KCl	29.0
1.0 N. KCl	25.6
1.5 N. KCl	23 0
1.0 N. K_2CO_3	28.
1.0 N. KNO_3	26.
1.0 N. $CaCl_2$	27.
1.0 N. $(NH_4)_2CO_3$	28.2

It will be seen that the lowering of the freezing increased with the concentration and that it varied but slightly among the different salt solutions of the same strength.

EFFECT OF THE DECOMPOSITION OF MANURE ON SOIL TEMPERATURE.

OBJECT AND METHOD OF EXPERIMENTATION.

It might be said that the farm soil receives its heat from four different sources: (1) from the direct radiation of the sun; (2) from the precipitation or condensation of aqueous vapor, (3) from the heated interior of the earth by conduction, and (4) from the decomposition of organic matter. The amount received from the last three sources is very small; it is the first source that contributes the greatest, if not the whole, of the warmth of the soil. The second and third sources are entirely beyond the control of man; the first can be controlled in an indirect way by modifying the color and water content of the surface soil; the fourth is the only one of the four sources which is practically entirely under the control of man, because he can add the organic matter to the soil.

The amount of heat liberated by the decomposition of organic matter is considerable if the action is complete and rapid—it is equal to the amount of heat of combustion. The decomposition process, however, as carried on under field conditions is very slow and hence the amount of heat given off is practically imperceptible.

The principal sources of organic matter in the soil are (1) vegetable matter and (2) animal manure. The first is practically unimportant so far as heat is concerned because in the spring the temperature of the soil is already sufficiently high enough for the germination of seed and growth of plants by the time the vegetation has grown large enough to be turned under. In the fall the soil temperature is also sufficiently high for the germination of seeds and growth of seedlings without the necessity of increasing it. Furthermore, at either season the amount of vegetation that can be turned under is so small in comparison with the great bulk of the soil that the warming effect resulting from the decomposition is practically nil.

The extent to which the second source of organic matter may increase the temperature of the soil will depend upon the freshness and quantity of the material. The statements in different textbooks vary upon this point. Some are to the effect that the decomposition of manure of any kind has practically no importance on the thermal relations of soils; others, that the influence is quite appreciable.

These statements or conclusions have been drawn from insufficient data. The amount of experimentation that has already been done on the subject is very meager. The most widely quoted work is that of Georgeson[20] who added 0.0, 10, 20, 40 and 80 tons of farm yard manure to a soil and studied its temperature. The experiment was performed by mixing thoroughly the soil and the manure, placing the mixture in wooden boxes without bottom and top and burying the latter in the ground up to the surface edge. He found that the temperature of the soil was increased with the increase of the application of manure. The

[20] Agricultural Science 1:251.

increase was greatest during the first five days and then rapidly diminished. At the end of 20 days the increase became almost imperceptible where only 10 tons of manure per acre had been applied but continued to be distinct where 40 and 80 tons were employed.

Wagner[21] conducted a somewhat similar field experiment with different kinds of manure and also some laboratory experiments. The field tests showed that the application of heavy dressings of fresh manure of horse, cow, sheep and hog, raised the temperature of the soil; the horse manure increased it the most, the cow the least, and the sheep and hog intermediately.

Spragg[22] attempted to study the effect of farm yard manure of horse, sheep, and cow under laboratory and field conditions. The data he obtained show that the rise of temperature as a result of these applications is practically nil.

Since our knowledge of this subject was very meager and since the foregoing works as well as the statements found in various textbooks are not concordant, it was deemed advisable to investigate the subject.

The research consisted in studying the effect of the decomposition of different kinds of fresh manure upon the temperature of soils, under laboratory or controlled conditions. The investigation was conducted in the following manner: Four-gallon earthenware jars were insulated on the inside with thick asbestos paper and on the outside with thick hair felt. The asbestos on the inside of the jars was paraffined in order to make it water proof. The reason for so insulating the jars was to prevent the loss of heat by conduction from the sides and bottom and thus imitate in a way natural conditions. In actual field conditions, the loss of heat takes place from the surface soil. To each pot was then added the same amount of a fine sandy soil, known as Jack pine sand. From each jar was then taken equal weights of soil to correspond to a depth of 6 inches. This soil was thoroughly mixed with the proper amount and kind of manure and put back into the pot, and water added to it to bring it to the required moisture content. Care was taken to have the same percentage of moisture in the soils containing different amounts of the same kind of manure. This, of course, necessitated the making of corrections for the different amounts of water contained in the various proportions of manure. The correction was made only within the various amounts of the same kind of manure and not among the different kinds. The soils, therefore, containing the different kinds of manure in the various proportions did not possess exactly the same moisture content. In order to prevent evaporation as much as possible the surface soil of each pot was also covered by a thick layer of quartz sand.

There were four experiments conducted. The first three dealt only with horse manure and the fourth with horse, sheep, and cow manure. Since the first three experiments were preliminary and the results obtained are in the same order as the corresponding series in the fourth experiment; also, for the sake of brevity, only the results of the latter will be presented here.

The three different kinds of manure, horse, sheep, and cow, were only

[21] Forsch. a. d. G. d. Agrik. Phy. V. : 373.
[22] Thesis. 1906. Mich. Agr. Coll.

about one day old when they were added to the soil. For convenience and comparison only the pure solid was used. They were employed in the proportion of 0.0, 5, 10, 20, and 40 tons per acre, and 100% of cow and horse. Their moisture content was determined and shown in the table below. It will be seen that their water content is different. No correction was made for these differences in the weight of the manure added to the soil, consequently the actual amount of dry matter was not the same. Since the moisture consists of urine and this undergoes fermentation, it also adds heat to the soil.

The preparation of the experiment including, the weight of the soil, name and amount of manure added, the moisture content, etc., are all shown together in the following table:

TABLE 90.—SHOWING PLAN OF EXPERIMENT.

Weight of soil.	Tons manure per acre.	Moisture of manure.	Percent moisture H. M. Expt.	Per cent moisture C. M. Expt.	Per cent moisture S. M. Expt.
396 lbs.	0.0	Horse	17.39	17.52	17.42
396 lbs.	5.0	84.05	17.39	17.52	17.42
396 lbs.	10.0	Cow	17.39	17.52	17.42
396 lbs.	20.0	84.00	17.39	17.52	17.42
396 lbs.	30.0	Sheep	17.39	17.52	17.42
396 lbs.	40.0	75.50	17.39	17.52	17.42

6 Kilos horse manure.
6 Kilos cow manure.

When the preparation of the experiment was complete the pots were placed in rows on a stand one foot from the ground and kept in a room whose temperature varied very little from day to day. The room was intended for refrigerating purposes and was ideal for keeping the temperature constant.

In the first three experiments the temperature readings were taken by means of mercury thermometers graduated to 1° Centigrade. The results obtained by them were not altogether satisfactory because they did not read closely enough. To obtain mercury thermometers of high precision and the large number required in the present extensive work, it would have entailed considerable expense. To overcome this difficulty, it was decided to use thermocouples in the present or fourth experiment. The principle of such instruments is based upon the fact that when two wires of dissimilar metals are connected end to end and one junction is kept at a constant and the other at a variable temperature, an electrical current is produced the amount of which is proportional to the difference in temperature between the two junctions. This electrical current is measured by the deflection produced on the galvanometer. The amount of electrical current is also influenced by the composition of the wires. The combination of certain kinds of elements produces a greater current than others.

The thermocouples used in the present work were made in this laboratory especially for the purpose. Their material consisted of No. 18 "advance" wire and No. 18 copper wire. They were constructed by

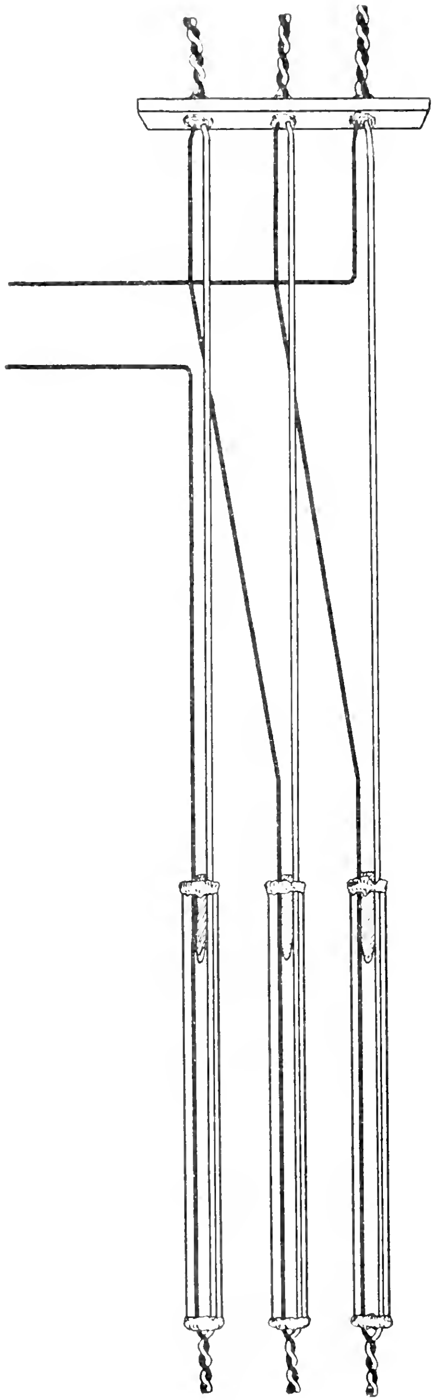

FIG. 54.

taking 25″ pieces of the respective wires and joining them in series of three. That is, three couples were joined together in series. The joints were first dipped in $ZnCl_2$, then soldered and finally coated with shellac. Above the joints, which were to be buried in the soil, were placed glass tubes 6 inches long and ¼ inch in diameter. The opposite ends of these glass tubes were made waterproof with shellac. These glass tubes were employed in order to facilitate the placing of the ends of the couples into the soil and also to keep the wires of the latter well insulated. To each series of couples were joined copper wires 12 feet long. All the couples were then standardized. This was accomplished by dipping one end of the series of couples in ice and the other in a constant temperature bath. It was found that they were all sensitive to about 0.2° C.

Those ends of the couples having the glass tubes were placed into the soil five inches deep from the lowest end of the point or four inches from the upper part of the joint. The three couples were placed at different places in the soil in order to obtain a more nearly average record. The temperature readings were made by dipping the long bended end (as shown in the diagram) into an ice bath, connecting the two 12 foot wires to the galvanometer, and reading the deflection on the latter. The galvanometer employed was of D'Arsonval type and was of very high grade. Its needle came to rest in a few seconds. It took only about 40 minutes to complete the reading of the 40 thermocouples. At the beginning of the experiment there were two readings made, one in the morning at 8:00 and one in the afternoon at 3:30. Later, however, the readings were made only in the afternoon. At the beginning also, the readings were taken every day but after the maximum temperature was attained they were taken every other day for some time and occasionally afterwards. The experiment lasted altogether from December 28th to April 10th, or 103 days. The data obtained are given herewith:

RESULTS OF EXPERIMENTS.

TABLE 91. EFFECT OF DECOMPOSITION OF MANURE ON TEMPERATURE OF SOILS.

1911.	December 28.			December 29.			December 30.			December 31.		
Amount in tons.	Horse.	Cow.	Sheep.	Horse.	Cow.	Sheep.	Horse.	Cow.	Sheep.	Horse.	Cow.	Sheep.
C°	C°	C°	C°	C°	C°	C°	C°	C°	C°	C°	C°	C°
0.......	15.4408	15.4408	15.4408	14.8954	14.8954	14.8954	15.0227	15.0227	15.0227	15.3863	15.3863	15.3863
Diff.....	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.......	15.4045	15.3378	14.9985	15.1015	15.5011	15.2712	15.2742	15.7075	15.4227	15.6529	16.0287	15.8105
Diff.....	-0.0363	0.1029	0.4423	0.2061	0.606	0.3758	0.2515	0.6848	0.4000	0.2666	0.6423	0.4241
10	15.4348	15.3015	15.0894	15.2409	15.5139	15.3015	15.5045	15.7560	15.4530	15.9317	16.0802	15.8590
Diff	-0.006	-0.1393	-0.3514	0.3455	0.6485	0.4091	0.4818	0.7333	0.4303	0.5454	0.6938	0.4726
20......	15.5984	15.4105	15.1803	15.6772	15.6014	15.4227	15.9832	15.8923	15.6045	16.3014	16.2377	15.9802
Diff.....	0.1576	-0.0302	-0.2605	0.7818	0.706	0.5273	0.9605	0.8696	0.5818	0.915	0.8514	0.5938
30......	15.7257	15.5742	15.5742	16.065	15.7923	15.6802	16.468	16.0438	15.8772	16.7498	16.4377	16.3256
Diff.....	0.2849	0.1334	0.1334	1.1696	0.8969	0.7848	1.4453	1.0211	0.8545	1.3635	1.0514	0.9392
40......	15.9681	15.7105	15.8166	16.7559	15.9529	15.9196	17.2101	16.2529	16.2041	17.4770	16.6589	16.6650
Diff.....	0.5273	0.2697	0.3758	1.8605	1.0575	1.0242	2.1877	1.2302	1.1817	2.0917	1.2726	1.2787
100%...	37.5	....	....	37.2000	19.33	....	38.3	18.693	....	37.500	18.729	......
Diff.....	22.0592	....	....	22.3046	4.4346	....	23.2773	3.6703	....	22.1136	3.3336	......
Air.....	....	....	....	......	....	16.665	....	......	16.8771	....	....	17.2710
Diff.....	....	....	......	.....	.....	2.7696	....	....	1.8554	....	.....	1.8847

TABLE 91,—Continued,

1912.	January 1.			January 2.			January 3.			January 4.		
Amount in tons	Horse.	Cow.	Sheep.	Horse.	Cow.	Sheep.	Horse.	Cow.	Sheep.	Horse.	Cow.	Sheep.
0.......	15.3015	15.3015	15.3015	15.2106	15.2106	15.2106	14.8954	14.8954	14.8954	14.6288	14.6288	14.6288
Diff.....	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.......	15.5863	16.0074	15.6651	15.5499	15.8469	15.453	15.1621	15.5105	15.0227	14.8470	15.2106	14.7621
Diff.....	0.2848	0.7059	0.3636	0.3393	0.6363	0.2424	0.2666	0.6151	0.1272	0.2182	0.5817	0.1332
10.....	15.859	15.962	15.7681	15.7620	15.9075	15.5257	15.3621	15.5136	15.2106	15.0833	15.2772	14.9379
Diff.....	0.5575	0.6605	0.4666	0.5514	0.6969	0.3151	0.4667	0.6181	0.3151	0.4545	0.6484	0.3090
20......	16.2105	16.1650	15.9014	16.0105	16.0408	15.6651	15.7135	15.6651	15.3621	15.3924	15.3863	15.0651
Diff....	0.9090	0.8635	0.5999	0.7999	0.8302	0.4545	0.8181	0.7696	0.4666	0.7636	0.7575	0.4362
30	16.6165	16.3347	16.1680	16.4226	16.2074	16.1317	16.1014	15.862	15.5863	15.8408	15.6135	15.3863
Diff.....	1.3150	1.0332	0.8665	1.212	0.9968	0.9211	1.2059	0.9665	0.6908	1.2120	0.9847	0.7574
40	17.3073	16.5225	16.4468	17.1982	16.4074	16.3711	16.7437	16.0108	15.9984	16.4529	15.765	15.6651
Diff.....	2.0058	1.221	1.1453	1.9276	1.1968	1.1635	1.8483	1.1453	1.1030	1.8241	1.1362	1.0332
100%...	37.1	18.666	....	34.5	18.666	.....	31.5	18.61		30.2	18.166	.
Diff.....	....	....	....	22.3046	4.4348	......	23.2773	3.8703	..	22.1136	3.3336	
Air.....	....	.....	17.8467		.	17.0589	......	.	16.5438	..	.	16.362
Diff.....	....	....	2.5452	...	.	1.8483	....	.	1.6484	... ...	......	1.7332

TABLE 91.—Continued.

1912.	January 5.			January 6.			January 7.			January 8.		
Amount in tons	Horse.	Cow.	Sheep.	Horse.	Cow.	Sheep.	Horse.	Cow.	Sheep.	Horse.	Cow.	Sheep.
0	14.0834	14.0834	14.0834	13.332	13.332	13.332	12.6018	12.6018	12.6018	11.8594	11.8594	11.8594
Diff	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	14.3925	14.7258	14.2046	13.744	14.0743	13.4226	12.8169	13.0714	12.7351	12.0775	12.4351	11.926
Diff .	0.3091	0.6424	0.1212	0.412	0.7423	0.0906	0.2121	0.4696	0.1333	0.2181	0.5757	0.0665
10 ..	14.5985	14.7561	14.3500	13.9016	14.1167	13.7632	12.9926	13.2138	12.8714	12.2109	12.4684	12.0351
Diff ...	0.5151	0.6727	0.2666	0.5696	0.7847	0.4312	0.3878	0.6090	0.2666	0.3514	0.609	0.1756
20 ...	14.8951	14.9318	14.5561	14.3117	14.2228	13.938	13.2714	13.3623	13.0714	12.5139	12.529	12.223
Diff ...	0.812	0.8484	0.4727	0.9797	0.8908	0.606	0.6666	0.7575	0.4666	0.6544	0.6696	0.3635
30	15.2863	15.0742	14.8773	14.5682	14.3319	14.1925	13.6471	13.5077	13.3141	12.829	12.7411	12.5442
Diff ...	1.2029	0.9908	0.7939	1.2362	0.9999	0.8505	1.0423	0.9029	0.7393	0.9696	0.8817	0.6847
40	15.8914	15.1803	15.3000	15.0166	14.5106	14.4228	14.0259	13.6017	13.5441	13.1077	12.8775	12.7684
Diff	1.718	1.0969	1.2196	1.6846	1.1786	1.0908	1.4241	0.9999	0.9393	1.2483	1.018	0.909
100% ...	26.75	17.638		23.65	18.083	.	21.00	16.22	..	19.50	15.38	......
Diff.....	12.6666	3.5546	..	10.318	4.751	..	8.3952	3.6152		7.6405	3.5205	......
Air.....	......	......	15.6045	....	.....	15.0591	....	..	13.8471	...	....	13.2841
Diff.....	......	......	1.5211	.	.	1.7271		...	1.2423	....	....	1.9816

TABLE 91.—Continued.

1912.	January 9.			January 10.			January 11.			January 12.		
Amount in tons.	Horse.	Cow.	Sheep.	Horse.	Cow.	Sheep.	Horse.	Cow.	Sheep.	Horse.	Cow.	Sheep.
0 .	11.3019	11.3019	11.3019	11.2716	11.2716	11.2716	11.5624	11.5624	11.5624	11.5867	11.5867	11.5867
Diff	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	11.5564	11.9321	11.4231	11.4473	11.8018	11.314	11.6836	11.923	11.4231	12.0472	12.0897	11.6473
Diff ..	0.2545	0.6302	0.1312	0.1757	0.5302	0.0424	0.1212	0.3605	0.1393	0.4605	0.5029	0.0605
10 ...	11.7806	11.9836	11.5261	11.6533	11.7776	11.4352	11.8412	11.9533	11.514	11.926	12.1503	11.7382
Diff .	0.4787	0.6817	0.2242	0.3817	0.5060	0.1636	0.2787	0.3908	0.0484	0.3393	0.5635	0.1514
20	12.0472	12.1351	11.7079	11.8779	11.9836	11.6473	12.1200	12.0847	11.7261	12.1200	12.2442	11.9503
Diff	0.7453	0.8332	0.406	0.606	0.712	0.3757	0.5575	0.5272	0.1636	0.5332	0.6575	0.3635
30	12.3563	12.2805	12.023	12.1806	12.1654	11.920	12.3502	12.2351	11.9503	12.4169	12.4078	12.1321
Diff	1.0544	0.9786	0.7211	0.909	0.8938	0.6484	0.7878	0.6726	0.3878	0.8302	0.8211	0.5453
40	12.6108	12.3624	12.223	12.4593	12.2533	12.1442	12.5684	12.3624	12.1684	12.6714	12.5229	12.3927
Diff	1.3089	1.0605	0.9211	1.1877	0.9817	0.8726	1.0059	0.7999	0.606	1.0847	0.9362	0.806
100% .	17.8	15.0		17.5	14.83		17.5	14.83		17.0	14.444	..
Diff	6.4981	3.6981		6.2284	3.5584		5.9375	3.2675		5.4132	2.8572	...
Air			12.8473			12.9987			13.3623			13.2411
Diff			1.5453			1.7271			1.7999		.	1.6544

TABLE 91.—Continued.

1912,	January 13,			January 14,			January 15,			January 16,		
Amount in tons.	Horse.	Cow.	Sheep.	Horse.	Cow.	Sheep.	Horse.	Cow.	Sheep.	Horse.	Cow.	Sheep.
......	11.1019	11.1019	11.1019	10.9383	10.9383	10.9383	11.0352	11.0352	11.0352	11.1501	11.1504	11.1504
Diff...	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.......	11.32	11.6867	11.7564	11.1625	11.3594	10.908	11.2655	11.6442	11.1504	11.2655	11.6139	11.6352
Diff.....	0.2181	0.5847	0.6544	0.2242	0.4211	-0.0303	0.2302	0.609	0.1151	0.1151	0.4635	0.5848
10......	11.4837	11.7412	11.3291	11.211	11.4231	11.014	11.514	11.7109	11.6352	11.4776	11.6745	11.2716
Diff	0.3817	0.6393	0.2271	0.2727	0.4848	0.0757	0.4787	0.6756	0.5999	0.3272	0.5241	0.1212
20......	11.7564	11.8473	11.5382	11.4231	11.5291	10.2413	11.6655	11.7867	11.4685	11.6836	11.8139	11.5291
Diff.....	0.6544	0.7453	0.4362	0.4848	0.5908	0.697	0.6302	0.7514	0.4332	0.5332	0.6635	0.3787
30......	12.0048	12.0048	11.7715	11.6533	11.6958	11.417	11.9321	11.923	11.6291	11.920	11.9988	11.6897
Diff	0.9029	0.9029	0.6695	0.715	0.7575	0.4787	0.8968	0.8877	0.5938	0.7696	0.8484	0.5393
40......	12.223	12.120	11.9533	11.9079	11.8018	11.6503	12.1503	12.026	11.7867	12.1321	12.1109	11.9351
Diff.....	1.1211	1.018	0.8514	0.9696	0.8635	0.712	1.115	0.9908	0.7515	0.9817	0.9605	0.7847
100%...	17.0	14.72	....	16.8	14.72	....	17.00	14.777	....	17.00	14.888	....
Diff.....	5.898	3.618	....	5.8617	3.7817	....	5.9647	3.7417	....	5.8496	3.7376	....
Air.....	....	....	12.5745	....	....	12.6957	....	....	12.5139	....	....	12.9987
Diff.....	....	....	1.4726	....	....	1.7574	....	....	1.4787	....	....	1.8483

TABLE 91.—Continued.

1912.	January 17.			January 19.			January 22.			January 24.		
Amount in tons.	Horse.	Cow.	Sheep.	Horse.	Cow.	Sheep.	Horse.	Cow.	Sheep.	Horse.	Cow.	Sheep.
0.......	11.5443	11.5443	11.5443	13.5138	13.5138	13.5138	13.8713	13.8713	13.8713	14.544	14.544	14.544
Diff.....	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5.......	11.6958	12.1806	11.6442	13.6471	14.044	13.6168	14.041	14.3076	13.9258	14.7076	14.9227	14.547
Diff.....	0.1515	0.6363	0.0999	0.1333	0.5302	0.103	0.1696	0.4363	0.0545	0.1636	0.3787	0.003
10......	11.9018	12.2078	11.7109	13.8471	14.044	13.6653	14.1622	14.3016	13.9804	14.8591	15.0288	14.6167
Diff.....	0.3575	0.6635	0.1666	0.3333	0.5302	0.1515	0.2908	0.4302	0.109	0.3151	0.4848	0.0727
20......	12.0594	12.2805	11.8624	14.047	14.1349	13.8117	14.3622	14.4015	14.0592	15.0894	15.1197	14.8864
Diff.....	0.5151	0.7362	0.3181	0.5332	0.6211	0.2979	0.4908	0.5302	0.1878	0.5454	0.5757	0.3424
30......	12.3563	12.4745	12.1866	14.2713	14.2955	14.0743	14.5864	14.5864	14.3682	15.3318	15.259	15.0288
Diff.....	0.812	0.9302	0.6423	0.7575	0.7817	0.5605	0.715	0.715	0.4969	0.7878	0.715	0.4848
40......	12.6048	12.6138	12.3927	14.5561	14.4803	14.2713	14.7682	14.7561	14.65	15.5257	15.4378	15.3166
Diff	1.0605	1.0695	0.8484	1.0423	0.9665	0.7575	0.8968	0.8847	0.7787	0.9817	0.8938	0.7726
100%...	17.00	15.222	....	18.90	16.388	. .	19.00	17.00	.....	19.50	17.777	.....
Diff....	5.4557	3.6777	......	5.3862	2.8742	......	5.1286	3.1286	......	4.956	3.233	.....
Air...		.	13.9077			15.8469		. .	15.7863	...		16.1390
Diff....			2.3634		.	2.3331		.	1.9150	.		1.6059

TABLE 91.—Continued.

1912.	January 30.			February 6.			February 14.			February 28.		
Amount in tons.	Horse.	Cow.	Sheep.	Horse	Cow.	Sheep.	Horse.	Cow.	Sheep.	Horse.	Cow.	Sheep.
0	13.8652	13.8652	13.8652	13.3804	13.3894	13.3804	13.1986	13.1986	13.1986	17.5012	17.5012	17.5012
Diff.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	13.9683	14.3803	14.0592	13.541	13.8349	13.3471	13.1986	13.1805	12.5654	17.6649	17.6649	17.271
Diff.	0.103	0.5151	0.1939	0.1606	0.4545	-0.0333	0.0	-0.0181	-0.6332	0.1637	0.1637	-0.2302
10	14.1076	14.1946	15.8317	13.7531	13.8986	13.3926	13.4229	13.2259	12.6199	17.7861	17.6649	17.271
Diff.	0.2424	0.5393	1.9664	0.3727	0.5181	0.0121	0.2243	0.0272	-0.5787	0.2849	0.1637	-0.2302
20	14.2773	14.3985	14.1804	14.0289	13.938	13.5834	13.6895	13.2411	12.7714	17.9679	17.6649	17.3017
Diff.	0.412	0.5332	0.3151	0.6485	0.5575	0.203	0.4909	0.0424	-0.4272	0.4667	0.1637	-0.1995
30	14.514	14.6046	14.3319	14.1501	14.1228	13.8107	13.7501	13.3623	13.1956	18.180	17.7558	17.6043
Diff.	0.6788	0.7393	0.4666	0.7697	0.7423	0.4302	0.5515	0.1636	-0.003	0.6788	0.2546	0.1031
40	14.7742	14.8167	14.6046	14.2561	14.3167	14.0831	13.8622	13.6895	13.332	18.283	18.0103	17.9973
Diff.	0.909	0.9514	0.7394	0.8757	0.9362	0.7029	0.6636	0.4908	0.1333	0.782	0.5091	0.4061
100	18.50	17.22	.....	18.00	17.22	....	17.00	17.00	....	22.00	20.5555	....
Diff.	4.6347	3.3547	...	4.6196	3.8395	....	3.8014	3.8014	.....	4.4988	3.0543	....
Air	....	...	15.1833	....	....	15.3015	....	....	17.8467	......	....	....
Diff.		..	1.6181	....	....	1.9211	....	....	4.6481	......	....	....

TABLE 91.—Concluded.

1912.	March 15.			March 27.			April 10.		
Amount in tons.	Horse	Cow	Sheep.	Horse.	Cow.	Sheep.	Horse.	Cow.	Sheep.
0	19.93	19.93	19.93	18.19	18.19	18.19	19.00	19.00	19.00
Diff	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	20.11	20.00	19.77	18.222	18.19	17.915	19.055	18.885	18.75
Diff	0.18	0.07	0.16	0.032	0.0	-0.275	0.055	-0.115	-0.25
10	20.22	20.00	19.77	18.25	18.205	17.94	19.055	18.885	18.75
Diff	0.29	0.07	-0.16	0.06	0.015	-0.25	0.055	-0.115	-0.25
20	20.25	20.00	19.77	18.38	18.205	17.985	19.055	18.885	18.75
Diff	0.32	0.07	0.16	0.19	0.015	0.205	0.055	-0.115	-0.25
30	20.27	20.16	20.05	18.555	18.320	18.205	19.333	19.110	19.00
Diff	0.34	0.23	0.12	0.365	0.13	0.015	0.333	0.110	0.0
40	20.50	20.27	20.16	18.665	18.470	18.320	19.525	19.250	19.165
Diff.	0.57	0.34	0.23	0.475	0.280	0.130	0.525	0.250	0.165
100	21.50	20.83		19.333	19.275		20.111	20.111	
Diff.	1.570	0.900		1.143	1.085		1.111	1.111	..
Air			18.7557				.	...	..
Diff			1.2545					...	....

TABLE 92.—EFFECT OF DECOMPOSITION OF MANURE ON TEMPERATURE OF SOIL. AVERAGES FOR THE WHOLE PERIOD.

Amount of manure.	Horse.	Cow.	Sheep.
	C°	C°	C°
0 tons	13.90	13.90	13.90
5 tons	14.10	14.35	13.98
10 tons	14.26	14.39	14.10
20 tons	14.50	14.48	14.13
30 tons	14.79	14.65	14.45
40 tons	15.13	14.81	14.70
100%	23.33	17.16	....
Air	....	....	15.13

The above tables contain the temperature in F. degrees for the days the records were made, the difference for the corresponding days between the 0.0 manure with any of the other amounts of manure, and the average temperature for the whole period or at the expiration of the experiment, for all the various amounts and different kinds of manure. The data show that in the first day of the experiment the temperature of the soil with the 5, 10, and 20 tons of manure of all three kinds, was lower than that of the soil with 40 tons and 100% of manure. At the end of the first day, or at the beginning of the second day, the temperature of all the soils containing the different manures in the various quantities was appreciably higher than that of the check and increased regularly and gradually with the increase in the amount of manure. The rise in all cases tended to increase till the maximum was reached and then showed a tendency to decrease but remained quite constant for a long period and varied with the air temperature. On account of the variation in air temperature it is somewhat difficult to state definitely when the maximum temperature was attained by all the different manures. The results seem to show, however, that this was attained at different days by the different kinds as well as by the different amounts of manure but practically on the third, fourth and fifth day. The larger quantities of every kind of manure attained the maximum temperature earlier than the smaller quantities. The horse manure attained the highest temperature first, followed by cow and sheep one day later. The magnitude of rise of temperature was also in the same order. The maximum temperature given by the 40 tons of the horse manure was 2.18° C., of the cow 1.27°, and of the sheep 1.28° and by the 10 tons of the horse manure .5696°, cow .7847°, and sheep .4312°. While the highest temperature reached by 100% horse manure was 23.27° C. and by the same percent of cow manure 3.67° C. The check or the unmanured soil was taken as a unit in every case.

After the highest point was reached the temperature began to decrease slowly but on the whole it remained quite constant almost to the end of January. During this time it varied from day to day with the air temperature. By the middle of February it began to become somewhat imperceptible among the different kinds of manure as well as among the different amounts within the same kind of manure. In fact

the temperature of the sheep manure began to become less than that of the check.

When the daily records, or for those days that the records were taken, are arranged in averages for the whole period, namely, from December 28th to April 10th, it is found that in every case the rise of temperature increased very regularly and gradually with the increase in the amount of manure so that the difference between the soil with no manure and that containing 40 tons of manure was for horse manure 1.23°, for cow manure .91°, and for the sheep manure, .80° C.; while the difference between no manure and 10 tons of manure was for the horse manure .30°, for cow .49°, and for sheep .20° C.

From these results it would seem that the application of 40 tons of manure and especially of horse manure, would raise the soil temperature quite appreciably above that of the unmanured soil and keep it warmer for a long period, but such heavy applications or dressings are very seldom applied. The most common and practical dressing is about 10 tons to the acre. This amount raised the temperature of the soil about half a degree and at the end of the whole period this soil was only about a quarter of a degree warmer than the wholly unmanured soil. This warmth or rise is unimportant for practical conditions; it is too small to have any important influence. Furthermore, when it is considered that the decomposition processes require a high temperature for their maximum activity, then manure, even in fairly large amounts, can add no or very little heat to the soil at the time when the latter needs it the most.

SUMMARY.

In this bulletin there is presented the results of an investigation upon the general subject of soil temperature. It was shown at the outset that the problem is very complex—it involves a variety of factors—and in order to arrive at proper and definite conclusions it must be studied from as broad a standpoint as possible. The attempt was made and the results obtained may be summarized as follows:

The specific heat of different types of soil, gravel, sand, loam, clay and peat, in dry condition did not differ very materially; this was true both by equal weights as well as by equal volumes. The specific heat of peat was about half as great as that given to it by other investigators. The moisture content of these different soils in their natural condition varied very greatly and since water has such high specific heat, it made a tremendous difference in their final specific heat.

The heat transference in these different soils was measured (1) in their dry condition; (2) in their natural state under laboratory conditions; and (3) under field conditions. It was found in all these three states that the order of heat conductivity was the same: gravel possessed the highest heat transmitting power, followed in order by sand, clay, loam and peat, respectively. Convectional currents, molecular diffusion and distillation influenced very greatly the rate of flow of heat, and consequently the values obtained do not represent the true heat conducting power of these different types of soil.

In field conditions, the solar radiation tended to travel with greater rapidity and facility vertically than horizontally.

The study on radiation showed that color had no effect upon radiation, which is contrary to the common belief, but it had upon absorption; that the different types of soil tended to radiate differently when dry, about the same and more when well moistened and in their natural condition, and that a dry surface or mulch reduced the radiation. In the dry state, sand exhibited the highest radiating power followed by gravel, clay, loam, and peat respectively. The water, however, had by far the highest radiation capacity of any soil either in the dry or moist state.

When the temperature of these different types of soil (all covered with a thin layer of the same kind of soil in order to eliminate the factor of color, and other factors) was studied under field conditions, it was found that they all cooled and froze about the same time in the upper 6 inches, but in the spring they thawed and warmed up at different rates. This was attributed to their different specific heats and to the downward and upward trend of air temperature in the fall and spring respectively. The gravel and sand thawed first, followed by clay 1 day later, loam 2 days later, and peat 10 days later. The temperature of the first two soils rose very rapidly after thawing, while that of the others rose very slowly. When the lower depths of the latter soils had thawed, however, their temperature rose also quite rapidly and finally reached the same degree of magnitude as in the former or lighter soils,

and all continued to have almost the same temperature from then on throughout the summer, autumn and winter.

This equal degree of warmth of all these different types of soil during the warm part of the year and especially during the summer season, was believed to be due largely to the thin layer of the same kind of soil with which they were all covered. This thin layer of soil tended to equalize the amount of heat that penetrated into these different kinds of soils by eliminating the differences of their color and by equalizing, to a large extent, the amount and rate of evaporation of their moisture. If it had not been for this external layer of soil these different soil types would have taken in unequal amounts of heat and consequently their temperature would have been different. This point, however, is now under investigation.

Of all these different types of soil, sand showed the greatest amplitude and was followed by gravel, clay, loam, and peat, respectively. The greatest monthly fluctuation for all soils occurred in June and the least in February.

The different meteorological elements played a great part in the temperature of these soils, but on account of the complexity of their behavior it was difficult to trace the direct influence of all of them. The influence of the most important ones was discussed in detail.

The results from the investigation on the effect of organic matter on soils temperature showed that the rate of thawing was about proportional to the amount of organic matter present, but that after thawing the temperature of the soils containing 2.01, 3.32, 5.47 and 6.95% organic matter was higher throughout the summer than the temperature of the white sand and of the peat. The temperature of these last two soils was about the same during the warmer part of the year, but during the cold seasons the peat had a higher temperature. The magnitude of the amplitude of all these soils behaved in the same order as the average temperature.

The conditions of cultivation, noncultivation and sod had a very distinct effect upon the soil temperature. During the winter all three plots had about the same temperature with a small difference in favor of the sod. In the spring the sod and uncultivated plots thawed first and the cultivated plot about one day later, at the 7 inches depth. The temperature of the sod plot rose several degrees above that of the other two plots and continued to be in excess until the plants had made a considerable growth, and then it dropped below that of the two bare plots, and remained so throughout the summer months, but when the cold period came the order was reversed,—the temperature of the bare plots fell below that of the sod plot and continued to be lower throughout the second winter. The temperature of the cultivated plot rose slightly higher than that of the uncultivated, after thawing, and continued to be slightly higher during the early part of the spring season or up to about the middle of May, and then the uncultivated plot became the warmer and remained so throughout the whole summer. During the fall both plots had about the same temperature with a slight difference in favor of the uncultivated plot. The difference in temperature between these two plots was explained upon the following general facts: (1) Different rate of evaporation; (2) different rate of heat conductivity; (3) differ-

ence in temperature at the lower depths, and (4) the effect of the dry mulch of the cultivated soil.

Salt solutions had a very marked influence on the rising and lowering of soil temperature. Different salt solutions of the same density or the same solution of different densities raised the soil temperature considerably. Their influence was also very pronounced on the rate and degree of lowering of temperature, as well as on the rate of thawing.

The different kinds of manure raised the soil temperature differently,—horse manure the most, sheep manure the least, and the cow manure intermediate. In every case the greatest rise took place in the first three or four days. The rise increased with the increase in quantity. The degree of rise is probably insignificant for practical conditions.

It is thus seen that the general subject of soil temperature is very complex, that the number of factors influencing it is very large, that the effect of these different factors may be direct or indirect, dependent or independent, large or small, and that some of these factors can be controlled and others cannot, for the final modification of soil temperature.

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The following laws passed by the legislature of 1913, with the administration of which the State Board of Agriculture is concerned, are here re-printed for the benefit of those who are interested in them.

The immediate administration of these acts has been placed in the hands of the following persons: The seed law, Dr. E. A. Bessey, Professor of Botany; the insecticide law, Professor A. J. Patten, Chemist of the Experiment Station; and the apiary law, Professor R. H. Pettit, in charge of the Department of Entomology.

ACT 202 P. A. 1913.

An Act to regulate commerce in certain agricultural seeds and for other purposes.

The People of the State of Michigan enact:

SECTION 1. For the purposes of this act, agricultural seeds are defined as the seeds of alfalfa, barley, Canadian blue grass, Kentucky blue grass, brome (awnless) grass, buckwheat, alsike clover, crimson clover, red clover, white clover, field corn, Kaffir corn, meadow fescue, flax, millet, oats, orchard grass, rape, red top, rye, sorghum, timothy and wheat which are to be used for sowing or seeding purposes.

SEC. 2. Every lot of agricultural seed as defined in section one of this act, which is offered or exposed for sale within this State for seeding purposes in this State in lots of eight ounces or more, shall be accompanied by a plainly written or printed statement in the English language stating, except where agricultural seed, as defined in section one of this act, is sold at retail from the original package, and said original package being marked in accordance with the provisions of this act:

1. Name of agricultural seed.
2. Name and address of person selling or offering for sale such seed.
3. The approximate percentage by weight of purity or freedom of such seed from foreign matter or from other seeds distinguishable by their appearance.
4. The approximate percentage by weight of contamination, specifying by name each kind present in greater proportion than one per cent by weight of the whole.

SEC. 3. The seeds of quack grass (Agropyron repens), Canada thistle (Cirsium arvense), clover and alfalfa dodder (Cuscuta epithymum) and field dodder (Cuscuta arvensis), are hereby defined as noxious weed seeds. No person or persons, firm or corporation shall by himself, his agent or representative of any other person, firm or corporation, offer or expose for sale or distribution for seeding purposes in this State, or

sow or cause to be sown in this State any agricultural seeds defined in section one of this act, containing a greater amount or proportion than one seed of any or all of said noxious weeds to two thousand seeds of the variety of agricultural seed sown, offered or exposed for sale.

SEC. 4. The percentage of purity of agricultural seeds required under section two of this act shall be based upon a test or analysis conducted either by the State Board of Agriculture or its employes, or by the vender of the agricultural seeds or his agents: Provided, That such test or analysis made by the vender or his agents, shall conform to the reasonable regulations which said board is hereby authorized and directed to prescribe or shall conform to the reasonable regulations or methods of testing adopted or used by the Association of Official Seed Analysts or the United States Department of Agriculture.

SEC. 5. Whoever buys or sells or sows agricultural seeds, defined in section one of this act for use in this State, for seeding purposes, may submit his samples of such seeds to the State Board of Agriculture for examination and test of purity, and said Board of Agriculture shall cause such examination to be made as promptly as possible and reported to the sender. For tests of purity, said Board shall charge a fee of twenty-five cents for the examination of each sample, which fee shall be payable in advance. All moneys received as such fees shall be paid to the State Board of Agriculture.

SEC. 6. The enforcement of this act shall be entrusted to the State Board of Agriculture, which is hereby authorized to appoint such inspectors, assistants and deputies as may be necessary to enforce this act and is authorized in person or by its inspectors or assistants to take for analysis, paying the reasonable purchase price, a sample not exceeding four ounces in weight from any lot of agricultural seeds offered or exposed for sale: Provided, That said sample shall be drawn or taken in the presence of the vender or parties in interest, or his or their agents or representatives, and shall be taken from a parcel, lot or number of parcels, which shall not be less than ten per cent of the whole lot inspected, and shall be thoroughly mixed and then divided into two samples and placed in containers, carefully sealed, and a label placed on each container stating the name of the agricultural seed sampled, the name of the vender and the date and place of taking such samples, and said labels shall be signed by said State Board of Agriculture or its agents; or said samples may be taken in the presence of two disinterested witnesses if the vender or party in interest fails or refuses to be present when notified. One of said duplicate samples shall be left with or on the premises of the vender or party in interest and the other retained by the State Board of Agriculture for analysis and comparison with the label required by section two of this act.

SEC. 7. The provisions of this act shall not apply to:

First—Any person selling agricultural seeds direct to seed merchants or shipping to a general market to be cleaned or graded before being offered or exposed for sale for seeding purposes;

Second—Agricultural seed which is held in storage for the purpose of being cleaned;

Third—Agricultural seed marked "not cleaned" and held or sold for shipment outside the State only.

SEC. 8. Whoever sells, offers or exposes for sale within this State

any agricultural seeds defined in section one of this act, without complying with the requirements of sections two and three of this act, or whoever falsely marks or labels any agricultural seeds under section two of this act, or whoever shall prevent the State Board of Agriculture or its duly authorized agents from inspecting said seeds and collecting samples as provided in section six of this act or whoever shall otherwise violate this act shall be guilty of a misdemeanor, and upon conviction shall be fined not more than one hundred dollars: Provided, however, That no prosecution for violation of this act shall be instituted except in the following manner: When the State Board of Agriculture believes or has reason to believe that any person has violated any of the provisions of section two, three and eight of this act, it shall cause notice of such fact, together with full specifications of the act or omission constituting the violation, to be given to said person, who either in person or by agent or attorney shall have the right, under such reasonable rules and regulations as may be prescribed by said State Board of Agriculture, to appear before said Board and introduce evidence and said hearing shall be private. If after said hearing or without such hearing, in case said person fails or refuses to appear, said State Board of Agriculture shall decide and decree that any or all of said specifications have been proven to its satisfaction, it may at its discretion so certify to the proper prosecuting attorney and request him to prosecute said person according to law for violation of this act, transmitting with said certificate a copy of the specifications and such other evidence as shall be deemed necessary and proper, whereupon said prosecuting attorney shall prosecute said person according to law.

SEC. 9. The results of the analyses and tests of seed made by the State Board of Agriculture may, at its discretion, be published in its reports.

SEC. 10. The necessary expense incurred in carrying out the provisions of this act shall be certified by the Secretary of the State Board of Agriculture to the auditor general, who shall thereupon issue his warrant upon the State treasurer for the payment thereof, but the total amount so paid in any one fiscal year shall not exceed two thousand dollars.

SEC. 11. The words "persons," "vender" and "party in interest" and "whoever," as used in this act, shall be construed to import both plural and singular as the case demands, and shall include corporations, companies, societies and associations.

SEC. 12. Act number two hundred eighty-nine of the Public Acts of nineteen hundred nine, and all acts or parts of acts inconsistent with the provisions of this act are hereby repealed.

Of particular interest to seed dealers throughout the state are the provisions of Sections 2, 3, 6 and 8. Whereas the present law provides that packages under one pound in weight do not come within the provision of the law, the new law lowers this limit to eight ounces. The most important provision, however, is that which provides that all such paskages, of eight ounces or more, offered for sale shall be labeled. This does not mean that it is necessary that there shall be formal printed labels although it is probable that wholesale dealers, both outside and in the state, will furnish such to retail dealers to be affixed to packages made up from the bulk seed sold by the wholesaler.

The features that will require the greatest care are those that require the approximate percentages by weight of purity and the approximate percentages by weight of contaminates, specifying the kinds that are present in quantities greater than one per cent and also the provision that no seeds may be sold or offered for sale that contain more than one seed in two thousand of quack grass, Canada thistle, and the two dodders mentioned. This point will make it necessary that the seed dealers or the wholesaler from whom the smaller dealers purchase their seed, must analyze their seed. In case this is done by the wholesalers or by the larger seed firms, these analyses will naturally be furnished to the retail dealers either on printed reports furnished by the wholesalers or on the label itself that is attached to the lot so that the retail dealer will be able to obtain his analysis in that way. However, where the retail dealer buys his seed from the growers, it will be necessary that he make an analysis before he can sell that seed. If it is not possible for him to make the analysis himself, he can have this made by another person who is competent to do the work or, on payment of twenty-five cents for each sample analyzed, can have it made by the State Board of Agriculture or more accurately, by the seed analyst appointed by the State Board of Agriculture and placed under the supervision of the Department of Botany of the College. In case the dealers make their own analyses, these should conform in general to the regulations and methods of testing used by the United States Department of Agriculture.

The Act does not apply to growers selling seeds to seed merchants or growers shipping seed to be cleaned and graded before being sold, or to seed which is held in storage for the purpose of being cleaned or for seed marked "not cleaned" and held or sold for shipment outside the state. The latter, however, must conform to the government regulation governing shipment of seed in interstate commerce.

Of interest to the consumers are the paragraphs concerning the purity of the seed. It is particularly desirable that consumers take great care not to buy seed that has not the proper labels as the very fact that this seed is not labeled should be prima facie evidence that the dealer is not conforming to the provision of the law. It should also be noted that seed containing quack grass, Canada thistle, and the dodders to the amount of one seed in two thousand is not only forbidden to be sold but also may not be sown.

Any further information concerning the law may be obtained from the Secretary of the State Board of Agriculture or from the Department of Botany at the Agricultural College, East Lansing, Michigan.

It is highly desirable that the newspapers call attention to this law as far as possible and that this information receive the widest possible diffusion in order that dealers and others may not violate the law in ignorance of its provisions.

ERNST A. BESSEY,
East Lansing, Michigan.

Act 254, P. A. 1913.

For preventing the manufacture, sale or transportation of adulterated or misbranded Paris greens, lead arsenates, and other insecticides, and also fungicides, and for regulating traffic therein.

The People of the State of Michigan enact:

SECTION 1. It shall be unlawful for any person to manufacture, sell, offer or expose for sale within the State of Michigan any insecticide, Paris green, lead arsenate, or fungicide which is adulterated or misbranded within the meaning of this act; and any person who shall violate any of the provisions of this act shall be guilty of a misdemeanor and upon conviction thereof shall be fined not to exceed two hundred dollars for the first offense, and upon conviction for each subsequent offense shall be fined not to exceed three hundred dollars, or sentenced to imprisonment in the county jail for a period not exceeding ninety days, or both in the discretion of the court.

SEC. 2. The State Board of Agriculture shall make uniform rules and regulations for carrying out the provisions of this act, including the collection and examinations of specimens of insecticides, Paris green, lead arsenates, and fungicides manufactured or offered for sale in the State of Michigan.

SEC. 3. The examination of specimens of insecticides, Paris greens, lead arsenates, and fungicides shall be made at the Agricultural College by such existing departments as may be directed by the State Board of Agriculture for the purpose of determining from such examination whether such articles are adulterated or misbranded within the meaning of this act; and if it shall appear from any such examination that any of such specimens are adulterated or misbranded within the meaning of this act, the State Board of Agriculture shall cause notice thereof to be given to the party from whom such sample was obtained. Any party so notified shall be given an opportunity to be heard, under such rules and regulations as may be prescribed as aforesaid, and if it appears that any of the provisions of this act have been violated by such party, then the State Board of Agriculture shall at once certify the facts to the attorney general, or prosecuting officer of the county in which the offense is committed, with a copy of the results of the analysis or the examination of such article duly authenticated by the analyst or officer making such examination under the oath of such officer. After judgment of the court, notice shall be given by publication in such manner as may be prescribed by the rules and regulations aforesaid.

SEC. 4. It shall be the duty of the attorney general or other prosecuting officer to whom the State Board of Agriculture shall report any violation of this act, to cause appropriate proceedings to be commenced and prosecuted in the proper courts of the State of Michigan without delay, for the enforcement of the penalties as in such case herein provided.

SEC. 5. The term "insecticide" as used in this act shall include any substance or mixture of substances intended to be used for preventing, destroying, repelling or mitigating any insects which may infest vegetation, man or animals, or households, or be present in any environment

whatsoever. The term "Paris green" as used in this act shall include the product sold in commerce as Paris green and chemically known as the aceto-arsenite of copper. The term "lead arsenate" as used in this act shall include the product or products sold in commerce as lead arsenate and consisting chemically of products derived from arsenic acid (H_3AsO_4) by replacing one or more hydrogen atoms by lead. The term "fungicide" as used in this act shall include any substance or mixture of substances intended to be used for preventing, destroying, repelling, or mitigating any and all fungi that may infest vegetation or be present in any environment whatsoever.

SEC. 6. For the purpose of this act an article shall be deemed to be adulterated, in case of Paris green:

First. If it does not contain at least fifty percentum of arsenious oxide;

Second. If it contains arsenic in water-soluble forms equivalent to more than three and one-half percentum of arsenious oxide;

Third. If any substance has been mixed and packed with it so to reduce or lower or injuriously affect its quality or strength.

In the case of lead arsenate:

First. If it contains more than fifty percentum of water;

Second. If it contains total arsenic equivalent to less than twelve and one-half percentum arsenic oxide (As_2O_5);

Third. If it contains arsenic in water-soluble forms equivalent to more that seventy-five one hundredths percentum of arsenic oxide (As_2O_5):

Fourth. If any substances have been mixed and packed with it so as to reduce, lower, or injuriously affect its quality or strength: Provided, however, That extra water may be added to lead arsenate (as described in this paragraph) if the resulting mixture is labeled lead arsenate and water, the percentage of extra water being plainly and correctly stated on the label.

In the case of insecticides or fungicides, other than Paris green and lead arsenate:

First. If its strength or purity falls below the professed standard or quality under which it is sold;

Second. If any substance has been substituted wholly or in part for the article;

Third. If any valuable constituent of the article has been wholly or in part abstracted:

Fourth. If it is intended for use on vegetation and shall contain any substance or substances which, although preventing, destroying, repelling, or mitigating insects, shall be injurious to such vegetation when used as recommended by the manufacturer.

SEC. 7. The term "misbranded" as used herein shall apply to all insecticides, Paris green, lead arsenates, or fungicides or articles which enter into the composition of insecticides or fungicides, the package or label of which shall bear any statement, design, or device regarding such article or the ingredients or substances contained therein which shall be false or misleading in any particular, and to all insecticides, Paris green, lead arsenates, or fungicides which are falsely branded as to the state, territory, or country in which they are manufactured. For the purpose of this act an article shall be deemed to be misbranded, in the case of insecticides.

Paris greens, lead arsenates and fungicides:

First, If it be an imitation or offered for sale under the name of another article;

Second, If it is labeled or branded so as to deceive or mislead the purchaser, or if the contents of the packages as originally put up shall be removed in whole or in part and other contents shall have been placed in such packages;

Third, If in package form, and the contents are stated in terms of weight and measure, they are not plainly and correctly stated on the outside of the package; in this connection it is held to be permissible to state the average net weight of the package.

In the case of insecticides (other than Paris green and lead arsenates) and fungicides:

First, If it contains arsenic in any of its combinations or in the elemental form and the total amount of arsenic present (expressed as per centum or metallic arsenic) is not stated on the label;

Second, If it contains arsenic in any of its combinations or in the elemental form and the amount of arsenic in water-soluble forms (expressed as percentum or metallic arsenic) is not stated on the label;

Third, If it does not state plainly upon the label the correct names and percentage amounts of each and every ingredient of the insecticide or fungicide having insecticidal or fungicidal properties and the total percentage of inert ingredients present.

SEC. 8. No dealer shall be prosecuted under the provisions of this act when he can establish a guaranty signed by the wholesaler, jobber, manufacturer, or other party residing in the State of Michigan from whom he purchased such articles, to the effect that the same is not adulterated or misbranded within the meaning of this act, designating it. Said guaranty, to afford protection, shall contain the name and address of the party or parties making the sale of such articles to such dealer, and in such case, said party or parties shall be amenable to the prosecutions, fines, and other penalties which would attach in due course to the dealer under this act.

SEC. 9. The word "person" as used in this act, shall be construed to import both the plural and the singular, as the case demands, and shall include corporations, companies, societies, and associations. When construing and enforcing the provisions of this act, the act, omission, or failure of any officer, agent or other person acting for or employed by any corporation, company, society or association, within the scope of his employment or office shall in every case be also deemed to be the act, omission, or failure of such corporation, company, society, or association as well as that of the other person.

SEC. 10. The necessary expense incurred in carrying out the provisions of this act, shall be paid by warrant of the auditor general drawn upon the state treasurer. Such expenses shall be certified to the auditor general by the State Board of Agriculture, but the total amount to be paid in any one fiscal year shall not exceed five hundred dollars.

SEC. 11. Act number ninety-one and act number one hundred sixty-three of the Public Acts of nineteen hundred nine, and all acts or parts of acts in conflict with the provisions of this act, are hereby repealed.

Act 200, P. A. 1913.

An act for the suppression of contagious diseases among bees in the State of Michigan, by creating the office of inspector of apiaries, to define the duties thereof, and to appropriate money therefor, and to repeal act number sixty-six of the Public Acts of nineteen hundred one, and all other acts and parts of acts inconsistent herewith.

The People of the State of Michigan enact:

SECTION 1. The State Board of Agriculture is hereby authorized to establish apiary inspection, and to appoint a competent person as chief inspector, who shall under the direction of said Board, have charge of the inspection of apiaries as hereinafter provided. Said inspector shall investigate or cause to be investigated outbreaks of bee diseases, and cause suitable measures to be taken for their eradication or control.

SEC. 2. The inspector shall, when notified in writing by the owner of an apiary, or by any three disinterested taxpayers, examine all reported apiaries and others in the same locality not reported, and ascertain whether or not the diseases known as American foul brood or European foul brood or any other disease which is infectious or contagious in its nature, and injurious to honey bees in their egg, larval, pupal or adult stages, exists in such apiaries; and if satisfied of the existence of any such disease, shall give to the owners or caretakers of the diseased apiaries, full instruction as to how to treat such cases: Provided, That if the colonies in question seem to be in such bad condition that treatment is not likely to be successful, or if it seems to the inspector that the chances of obtaining a cure are remote, and of this the inspector shall be the sole judge, it shall be the duty of the inspector to destroy said colonies by fire or burying or by both, without recompense to the owner, lessee or caretaker of said bees. He may also inspect apiaries in localities not reported, in endeavoring to locate new areas of infection.

SEC. 3. The inspector shall, if possible, visit all diseased apiaries a second time after ten days from the time of the first visit, unless he has reasonable assurance that his directions have been carried out, and if need be, without recompense to the owner, lessee, or agent thereof, he may destroy, in such manner as to avoid as far as possible, spreading the disease, all colonies of bees that he may find still diseased, together with the hives and all honey and appliances which may spread disease: Provided, That when the finding of the disease occurs in its incipient stages very late in the season after the honey flow has ceased, and after it is too late to successfully treat and feed, the treatment may be deferred until the following spring, if such delay is necessary in the judgment of the inspector.

SEC. 4. If the owner, possessor, agent or lessee of an apiary, honey or appliances, wherein disease is known to the owner, possessor, agent or lessee to exist, shall sell, barter or give away or remove from the premises, without the consent of the inspector, any bees from diseased colonies, be they queens, drones, or workers, honey or appliances, or expose other bees to the danger of such disease, said owner shall, on conviction thereon be punished by a fine of not less than ten dollars nor

more than fifty dollars and costs of prosecution: Provided, That bees may be shipped without honey or feed containing honey, also provided that honey may be sold in tight containers for commercial purposes, other than with bees or as food for bees.

SEC. 5. For the enforcement of the provisions of this act, the State inspector of apiaries shall have access, ingress and egress to and from all apiaries or places where bees, combs, or apiary appliances are kept; and any person or persons who shall resist, impede or hinder in any way, the inspector of apiaries in the discharge of his duties under the provisions of this act, shall on conviction thereof be punished by a fine not less than ten dollars nor more than fifty dollars and costs of prosecution, or be imprisoned in the county jail not less than ten days nor more than thirty days, or both at the discretion of the judge.

SEC. 6. After inspecting infected bees or fixtures, or handling diseased bees, the inspector shall, before leaving the premises, or proceeding to any other apiary, take such measures as shall prevent the spread of the disease by infected material adhering to his person or clothing or to any tools or appliances used by him, which have come in contact with infected materials.

SEC. 7. It shall be the duty of any person in the State of Michigan, engaged in the rearing of queen bees for sale, to use honey in the making of candy for use in mailing-cages, which has been boiled for at least thirty minutes, unless candy which contains no honey at all is used. Any such person engaged in the rearing of queen bees shall have his or her queen rearing and queen mating apiary or apiaries inspected at least twice during each summer season by the inspector of apiaries, and on the discovery of the existence of any disease which is infectious or contagious in its nature and injurious to bees in their egg, larval, pupal, or adult stages, said person shall at once cease to ship queen bees from such diseased apiary until the inspector of apiaries shall declare the said apiary free from disease. On complaint of the inspector of apiaries or of any five bee-keepers in the State, that said bee-keeper, engaged in the rearing of queens, is violating the provisions of this section, he shall upon conviction, be punished by a fine of not less than twenty dollars nor more than fifty dollars.

SEC. 8. It shall be the duty of any person in the State of Michigan engaged in bee-keeping to securely and tightly close the entrance of any hive or hives in apiaries not free from disease in which the bees shall have died either during the winter or at any other time, and to make the hive or hives tight in such manner that robber bees shall not find it possible to gain ingress or egress to and from such hives or to obtain honey from such hives. The sealing of the hives must be maintained so long as the hives remain in the yard or in any place where honey bees can gain access to them, and failure to comply with this provision shall constitute a misdemeanor, and on conviction thereof, he or she shall be punished by a fine of not less than five dollars nor more than twenty-five dollars for each offense.

SEC. 9. It shall be the duty of any one keeping bees in the State of Michigan, to deeply bury all combs and frames taken from diseased colonies, in places where they shall remain undisturbed, unless they be placed in tight receptacles so constructed that it shall be impossible for bees to gain access to combs, or for honey or any other liquid to

leak out where bees can gain access to it. Anyone knowingly exposing comb, honey, frames, quilts, empty hives, covers or bottom-boards, or tools or other appliances contaminated by infected material from the same, from diseased colonies, shall on conviction thereof, be punished by a fine of not less than twenty-five dollars nor more than fifty dollars: Provided, That the wax may be rendered in such place or at such time that no bees will be able to gain access to the comb before it is thoroughly heated, or at any time to the liquids expressed in the process of rendering.

Sec. 10. All colonies of bees and all nuclei which is brought into the State of Michigan from other states or from other countries, not accompanied by a certificate of health from the official inspector of the place from whence they came, shall be reported immediately to the State inspector of apiaries, and such colonies or nuclei shall be inspected by him at such time as is expedient. Failure to report such importation of bees shall, on conviction thereof, be punishable by a fine of not less than one dollar for each colony or nucleus.

Sec. 11. The State inspector of apiaries shall receive such compensation as the State Board of Agriculture shall determine, and said inspector shall render annual reports to the State Board of Agriculture, giving the number of apiaries visited, the number of diseased apiaries found, the number of colonies treated, also the number of colonies destroyed, and the expense incurred in the performance of his duty. He shall also keep a careful record of the localities where the disease exists, but this record shall not be public, but may be consulted with the consent of the inspector of apiaries.

Sec. 12. For the purpose of carrying out the provisions of this act, there is hereby appropriated out of the moneys in the State treasury not otherwise appropriated, the sum of fifteen hundred dollars per annum, or so much thereof as may be necessary, and all moneys appropriated under this act, or so much thereof as may be necessary to carry out its provisions, shall be expended by the inspector of apiaries under the direction of the State Board of Agriculture, and the same shall be drawn from the treasury upon presentation of proper certificates of said Board to the auditor general, and his warrant to the State treasurer.

Sec. 13. Act number sixty-six of the Public Acts of nineteen hundred one and all acts and parts of acts inconsistent herewith are hereby repealed.

RULES AND REGULATIONS IN RELATION TO THE INSECTICIDE LAW.

Act 254, P. A. 1913.

By action of the State Board of Agriculture the Division of Chemistry of the Experiment Station has been charged with enforcing the provisions of the law. All labels, therefore, should be submitted to the Chemical division for approval. Since the law has been patterned after the Federal Insecticide Law all labels approved by the Federal Insecticide Board will, so far as possible, be allowed in Michigan.

An inspection and analysis of all insecticides sold in the state will be made each year and the results published. The Chemical division

cannot undertake to analyze insecticide samples sent in by residents of the state unless they are received in original, unbroken packages or, if taken from bulk packages unless accompanied by a statement that the samples were taken in such a manner as to fairly represent the contents of the packages. Such samples must be forwarded in sealed packages in order to prevent evaporation of moisture. The taking of a sample and the accompanying statement must be witnessed by a responsible party other than the dealer.

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